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Friction and Lubrication

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A HAND-BOOK

For Engineers, Mechanics, Superintendents and Managers

—BY—

WILLIAM M. avis DAVIS

Member of
National Association of Stationary Engineers, Engineers Society of Western Pennsylvania and Ohio Society of Mechanical, Electrical
and Steam Engineers

ILLUSTRATED

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PITTSBURGH, PA.

1903

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To my Friend

and former Employer,

JOB ABLETT,

of Allegheny, Penna.

This Book is Respectfully

Dedicated.

Release 12-11-41 MJ 2

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PREFACE.

The subject of lubrication and lubricants from a practical or rather a mechanical point of view has not received the attention at the hands of learned and expert writers that it deserves.

In these days of rigid economies and close attention to details the engineer or manager who desires to attain the greatest efficiency and economy in the operation of the machinery in his charge must consider closely the cost, the quality and the best methods of applying lubricants, as well as of fuel and the other elements which enter into operation of a steam plant.

A few books have been written on lubricants by chemists, treating these subjects wholly from a chemical standpoint; these are of great value to those who have a knowledge of chemistry, but have little of value to the mechanical man.

The author, an engineer himself, has been for the past ten years in a position to make a close study of lubrication on many kinds of engines and machinery and under all sorts of conditions.

In presenting this book to the notice of those who have to do with the use of lubricants, while he has not endeavored to exploit any new theories, the author has kept in mind the fact that engineers, managers and mechanics are busy men and he has therefore tried to present the matter in a plain concise way that will be readily understood by readers and be of practical value in their every day work.

The thanks of the author are due to and are hereby acknowledged to, Mr. Charles Welsh, the author of "Publishing a Book," etc., Boston, Mass., for advice and assistance in preparing the manuscript for the publisher, correcting proofs, etc.; to Mr. Harrison W. Craver, librarian in charge of technical literature at the Carnegie Public Library, Pittsburg, Pa., for assistance in procuring information, data, etc., and to the manufacturers of appliances and devices and others who are mentioned by name in the body of the book, for information, use of cuts, etc.

FRICTION AND LUBRICATION.

FRICTION.

Friction has been aptly described as the "Highway robber of mechanical energy," levying tribute on all matter in motion, exerting a retarding influence and requiring power to overcome it.

When one realizes that if it were not for the thin film or layer of oil between the surface of the journals and their bearings and the constant supply of oil to maintain this film, the largest locomotive could not start a heavy train or keep it in motion, or the most powerful marine engine could not drive the ship a mile without heating of the bearings, one readily understands that a knowledge of lubrication and friction and of the laws relating to friction is a very important part of the training of an engineer.

LAWS OF FRICTION.

Friction is defined as the resistance caused by the motion of a body when in contact with another body that does not partake of its motion.

There are five commonly accepted and fundamental laws relating to the friction of plane surfaces in contact.

First.—Friction will vary in proportion to the pressure on the surfaces. That is, increasing the pressure increases the friction.

Second.—Friction is independent of the areas of the contact surfaces when the pressure and speed remain constant. But distributing the pressure or friction over a larger area renders the liability of heating and abrasion less than if the friction had been concentrated on a smaller area.

Third.—Friction increases with the roughness of the surfaces and decreases as the surfaces become smoother.

Fourth.—Friction is greatest at the beginning of motion. In the effort to move a body greater force is required to overcome the friction at the instant of starting than after motion has commenced.

Fifth.—Friction is greater between soft bodies than between hard bodies.

These rules hold good within certain limits but will fluctuate under varying conditions of load and lubricant, and condition and composition of the contact surfaces.

In 1831, 1832 and 1833 General Arthur Morin, a French engineer, made numerous experiments of friction of plane surfaces in contact and formulated the above laws and for a number of years they were considered invariable, but numerous experiments in recent years by Woodbury, Thurston, Hall, Denton, Dudley, Hirn and others have proven that these laws are not rigid, and that the laws as laid down by Morin can only be accepted in so far as they relate to the friction of dry surfaces in contact, or lubricated surfaces running under light pressures and at slow speed.

Friction is always a resisting and a retarding force, tending to bring everything in motion to a state of rest, and in doing so results in the convertion of energy into heat, it has been calculated that one horse power or 33,000 foot pounds exerted in overcoming friction results in the conversion of energy into 43 British Thermal Units of heat.

In the case of machinery in motion the surfaces moving in contact have a tendency to adhere to each other; the minute projections which exist on all surfaces to a greater or less extent (depending upon the hardness and smoothness of the surfaces) have a tendency to cling to each other and in order to operate machinery without undue friction the surfaces must be kept apart, something must be used that will flow or spread out over the surfaces and cover up these projections and prevent the surfaces from coming direct in contact, for which purpose lubricants of various grades are used.

USES OF FRICTION.

Yet, friction in mechanics has its uses; it is the friction, or adhesion (as it is sometimes called) of the driving wheels to the rails that enables a locomotive to start and keep in motion a heavy train, it is the friction of the brake shoes on the wheels as applied by the air brakes that stops the train, it is the friction of the belt on the pulley that enables power to be transmitted from one piece of mechanism to another.

Friction as it occurs in mechanics is what is known as friction of solids and friction of fluids; friction of solids may be divided into two classes, namely: rolling friction, such as a journal revolving in its bearing, or a crank pin in its brasses; and sliding friction, such as a crosshead on the guide bars.

COEFFICIENT OF FRICTION.

The relation that the power required to move a body bears to the weight or pressure on the body is known as the coefficient of friction, or, to put it in another form, the co-efficient of friction is the ratio between the resistance to motion and the perpendicular pressure, and is determined by dividing the amount of the former by the latter.

One of the simplest methods of demonstrating graphically the simple laws of friction of plane surfaces and the determination of the coefficient of friction is by drawing a block of iron or other metal across a table or an iron plate by means of weights suspended to a cord which is attached to the block as shown in Figs. 1 and 2.

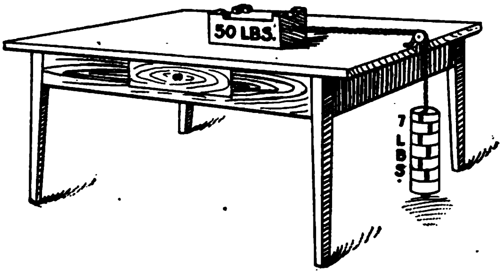

Fig. 1. Illustrating Laws of Friction.

It is noticed that the block is flat on one side, and on the other side are four small projections or legs, each one square inch in area, the size of the block is 12 inches long, 8 inches wide and 2 inches thick, and weighs 50 pounds. If we lay the block with its largest surface down it will have a surface contact with the table of 96 square inches and placing weights on the cord until the block commences to move we find that it requires a weight of 7 pounds to pull it across the table, now if the block be turned upside down so that it rests on the four legs it will be found that it requires exactly the same amount of force to move the block that it had before.

As we have found by experiment that to move the weight of 50 pounds required a force or pull of 7 pounds, the co-efficient of friction in this case will be found by dividing the pull by the weight, $7 \div 50 = .14$, or, to put it in another form, it will require .14 of a pound of force to move 1 pound of weight.

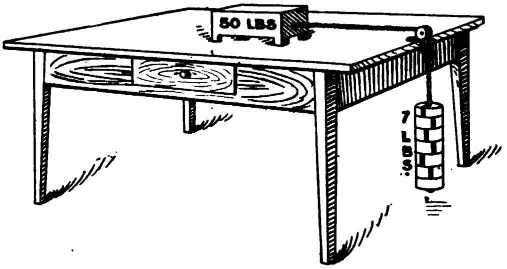

Fig. 2. Illustrating Laws of Friction.

The second law states that friction is independent of the areas of the surfaces, it has been found by experiment that it required a pull of 7 pounds to move the block no matter which side it stood on.

Let us prove this.

The block when on its largest side had a surface contact of 8″x12″, or 96 square inches and exerted a pressure due to its weight of 50 lbs., or .52 of a pound per square inch of area. The co-efficient has been found to be .14, then the pull per square inch of surface would be

.52x.14=.0729, which multiplied by the total area, 96 sq. in., will be found to be 6.9888 or practically 7 pounds.

Now, when the block was reversed and stood on the four legs of 1 sq. in. each, the total contact was only 4 sq. inches, but the pressure (50 pounds), remained the same, 50÷4=12.5 pounds per square inch, which multiplied by the co-efficient .14 equals 1.75, then again multiplying this result by 4 sq. in. again gives a total of 7 pounds.

Thus it will be seen that the extent of surfaces has no influence on the friction as long as the pressure or weight is constant, but in machine design increasing the area of surface contact allows the total pressure to be distributed over a greater area and reduces the liability of heating and abrading, or in other words, while the total pressure remains the same the pressure per square inch will be less.

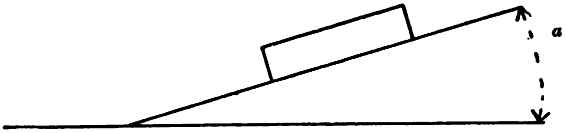

Fig. 3.

Another method of determining the coefficient of friction, or, as it is usually termed, the angle of friction, can be illustrated by means of a weight on an inclined plane.

Place a weight on a board or other plane surface and raise one end slowly as in Fig. 3 until the weight commences to slide; the angle "a" between the position of the plane surface when the weight commenced to move and the horizontal is the angle of friction, and will vary with the smoothness of the surfaces and the weight or pressure.

The angle of friction indicates the point where the attraction of gravitation just overcomes the friction between the surfaces.

To find the amount of power absorbed by friction multiply the weight by the coefficient of friction, multiply the result by the velocity in feet per minute and divide that by 33,000.

For instance, a shaft and fly wheel weighs 8,000 pounds, surface travel of journals is 300 feet per minute, the coefficient of friction is taken as being .04.

What would be the horse power required to run the shaft?

$$\frac{8{,}000 \text{ x } .04 \text{ x } 300}{33{,}000} = 2.909 \text{ H. P.}$$

While the coefficient of friction must always be taken into consideration when designing and constructing machinery, it is not always practicable to calculate it with any degree of accuracy, in fact it can only be determined absolutely by experiment.

As Mr. Hall in his work on Car Lubrication, has said: "There is no other element in connection with the lubrication of machinery that has received so much consideration as that of the coefficient of friction, and yet there is no other that is in so indeterminable a state; as investigation progresses the subject seems surrounded with more and more variables of a complicated nature which indicates the importance of the utmost care when the best results from lubrication are desired."

In other words, determining the coefficient of friction is in some respects much like the definition of the practice of medicine, given by a certain famous physician, when he spoke of it as the "science of guess work."

The coefficient of friction will vary largely with the different kinds of metals, the lubricant, the pressure, temperature, and velocity. The experiments of Prof. Thurston with steel journals running in bronze boxes and lubricated with sperm oil gave some curious results.

For instance with a speed of 30 feet per minute, 200 pounds pressure per square inch on the journal and at a temperature of 90 deg. the coefficient was .0056, by increasing the temperature to 150 deg., leaving the other conditions the same, the coefficient rose to .05. Again, with 1,200 feet per minute, 200 pounds pressure per sq. inch, and a temperature of 90 deg. the coefficient was .601, then by increasing the temperature to 150 deg. without making any other change it fell to .006; with 100 feet per minute and 50 pounds pressure the coefficient was .0037 and did not change when the temperature varied by ten degrees in each experiment, from 90 deg. to 150 deg. Fahr.

FRICTION LOSSES.

In a manufacturing or other power using establishment it is very important that the loss of power due to friction be kept to as low a point as possible.

By making the bearings of proper proportions, by the use of bearing metals having the greatest anti-friction value, by keeping the shafting in line, and by the use of the best and most suitable lubricants and lubricating appliances and by the substitution of self-oiling bearings, or of ball or roller bearings for the ordinary form of bearing, wherever possible, the friction losses can often be brought down to a small per centage of the total power developed.

Until within recent years the friction losses of well constructed stationary engines often amounted to 15 or 20 per cent. of the total power developed, but to such a state of mechanical refinement has modern engine construction been brought that the friction horse-power often amounts to only 2 or 3 per cent.

This low per cent. of friction loss has been brought about in the case of high speed engines by proper proportioning and balancing of the rotating parts, and by the use of self-oiling bearings arranged so that the moving parts are kept continuously flooded in a bath of oil, thus keeping the wearing surfaces from direct contact with each other to as great a degree as possible.

Dr. Thurston, Director of Sibly College of Mechanical Engineering, Cornell University, in an interesting paper on "The Distribution of Internal Friction" (Trans. Am. So. Mech. Eng's. Vol. 10.) states "that as the result of a large number of experiments, that the greatest friction loss in a stationary engine occurs in the main bearings, and in every instance it amounted to from one-fourth to one-third of the total frictional resistance of the engine."

PER CENT. OF FRICTION IN ENGINE PARTS.

He states "that the coefficient of friction could only be deduced with any degree of certainty for the main journals of the engines as there is a variation of pressure on the piston rings, stuffing boxes, and also in the guide bars and crank pins due to the angularity of the connecting rod which is to a great extent unknown."

He sums up the results of these tests in table 1 and 2, page 13. Table (1) gives a summary of the distribution of friction in the moving parts of four different engines, while table (2) shows the friction horse power absorbed by the main bearings, and the coefficient of friction of the main bearings with the engines running both light and loaded.

It will be noticed that the test of the "Straight Line" engine was made with both balanced valve and un-balanced valve, showing a decrease in friction in this case of 23.9 per cent. by the use of a balanced valve.

FRICTION OF LOCOMOTIVE SLIDE VALVES.

Prof. Frank Wagner, in an interesting paper presented at the December, 1899, meeting

TABLE I.

DISTRIBUTION OF FRICTION.

Summary of Results.

PERCENTAGES OF TOTAL FRICTION.

Parts of Engine.	Straight Line 6 x 12 Balanced Valve.	Straight Line 6 x 12 Unbalanced Valve.	7" x 12" Lansing Iron Works—Traction-Locomotive Valve Gear.	12" x 18" Lansing Iron Works — Automatic Balanced Valve.	21" x 20" Lansing Iron Works — Condensing Balanced Valve.
Main Bearings	47.1	35.4	35.0	41.6	46.0
Piston and Rod	32.9	25.0	21.0		
Crank Pin	6.8	5.1	13.0	49.1	21.0
Cross Head and Wrist Pin	5.4	4.1			
Valve and Rod	2.5	26.4	22.0	9.3	21.0
Eccentric Strap	5.3	4.0			
Link and Eccentric			9.0		
Air Pump					12.0
Totals	100.0	100.0	100.0	100.0	100.0

TABLE II.

COEFFICIENT OF FRICTION FOR THE MAIN BEARINGS OF STEAM ENGINES.

Engines.	F. H. P. due to Main Journals.	Weight of Journals in Pounds.	Weight on Journals in Inches.	Coefficient of Friction, Engine Light.	Coefficient of Friction, Engine Loaded.	Revolutions of Journal Per Minute.
6"x12" Straight Line..	0.85	1500	3	.10	.06	230
*12"x18" Auto. (L. I. W.)	3.70	2600	5	.19	.05	190
7"x10" Trac. (L. I. W.)	0.68	500	2	.31	.08	200
21"x20" Cond. (L. I.W.)	3.30	4000	5½	.09	.04	206

*The 12"x18" automatic engine was new, and gave, throughout, an excessive amount of friction as compared with the older engines of the same class and make.

of the Am. So. Mech. Eng's., and forming part of Vol. 21 of the transactions, mentions a test made by Messrs. Butler and Crebs at the Rose Polytechnic Institute, Terre Haute, Indiana, to determine the power required to move a locomotive slide valve.

The locomotive was blocked up and the slide valve and link so arranged as to be operated by an electric moter and the power developed measured electrically.

Two tests were made, one with a steam chest pressure of 42 pounds per sq. inch, and the other with 122 pounds, the net rubbing surface on the bottom of the valve was found by subtracting from the total rubbing surface on the face of the valve the average amount of such surface which was over the ports during one stroke of the valve. In calculating the force with which the valve is pressed upon its seat, allowance was made for the upward pressure on the portions of the valve which was over the steam ports.

The oil used to lubricate the valve during these tests was the regular brand used by the Vandalia Railroad Co.

Table (3) gives the dimensions of the valve, valve seats, and port openings; while table (4) gives a summary of the tests.

TABLE III.

DIMENSIONS OF VALVE.

From Wagner's Friction Tests of Locomotive Slide Valves.

Type of valve	D slide
Width of valve, inches	9.25
Length of valve, inches	17.00
Width of port opening, inches	1.25
Length of port opening, inches	15.00
Width of exhaust port, inches	2.50
Width of bridge, inches	1.25
Steam lap, inches	0.875

Exhaust lap, inches	0.125
Gross area of valve, square inches	157.25
Balanced area of valve, square inches	54.50
Unbalanced area of valve, square inches	102.75
Total bearing area of packing strips, square inches.	22.20
Gross rubbing surface, bottom of valve, square inches	86.00
Average net rubbing surface, bottom of valve, for 3-inch stroke, square inches	58.20
Rubbing surface, top of valve, square inches	22.20

TABLE IV.

FRICTION OF VALVE—SUMMARY OF TESTS.

From Wagner's Friction Tests of Locomotive Valves.

Number of test	1.	2.
Duration of test, hours	2.25	0.62
Number of observations	10.	3.
Double strokes of valve per minute	421.	410.
Speed of valve, feet per minute	210.5	205.
Average steam pressure in boiler, pounds per square inch	144.9	154.
Average steam pressure in steam chest, pounds per square inch	42.18	122.0
Downward force on valve due to pressure in steam chest, pounds	4,334.	12,534.
Average upward force on valve due to pressure in steam cylinder, pounds	373.	596.
Net force pressing valve upon its seat, pounds	3,961.	11,938.
Intensity of pressure between rubbing surfaces, face of valve, pounds per in.	68.	205.1
Intensity of pressure between rubbing surfaces, packing strips, pounds per square inch	42.18	122.0
Average power delivered to electric motor during test, horse-powers	4.85	7.45
Power consumed in driving motor and link-work, horsepowers	3.30	4.14
Net power consumed in driving valve, horse-powers	1.55	3.31
Average power required to move valve, pounds	243.	533.
Drops of oil fed to valve per minute	20.	15.
Coefficient of friction	.050	.036

FRICTION LOSS IN PISTON ROD PACKING.

In calculating the losses due to friction in an engine one must consider the power absorbed by

the friction in the stuffing boxes of the piston rods and valve stems.

In many cases where the packing is unsuitable or has become hard from continued use or has been screwed up too tightly, the resultant friction will require a good per cent. of the total power to overcome it.

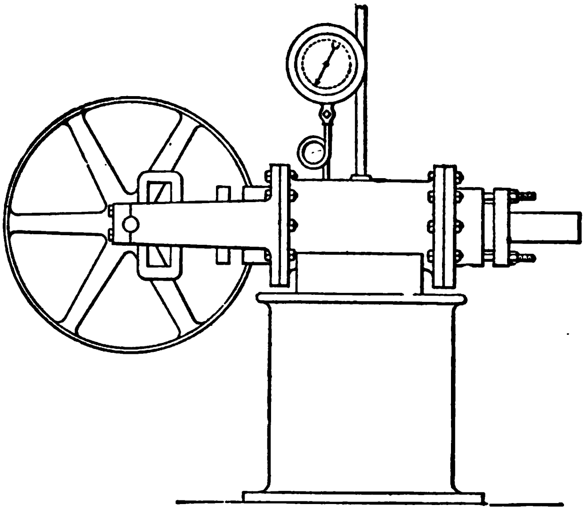

Fig. 4. Machine for Testing Friction of Piston Rod Packing. Exterior View.

Prof. Chas. H. Benjamin, in a valuable paper presented at the December, 1900, meeting of the Am. Soc. Mech. Eng's., gives the particulars of a number of tests made under his direction at the Case School of Applied Science in Cleveland, O., to determine the amount of friction caused by different kinds of packing.

A special appliance was designed by Mr. E. O. Leighly, a student, and a number of tests made by him and Mr. G. S. Beckwith. Figs. 4 and 5 show views of the machine used. Seventeen different kinds of packing were used, the materials of which were rubber, cotton, asbestos, hemp, lead and flax; some of which were combined with mica, graphite, and paraffine.

The aparatus for making these tests consisted of a cast iron cylinder 6″x12″ inside, fitted at each end with a cover and stuffing box suitable for a 2″ piston rod, the rod was given a reciprocating motion by means of a slotted crosshead and crank, and a pulley on the crank shaft was connected by belt to a dynamometer. Steam was admitted to the cylinder through the pipe shown in Fig. 4, and the condensed water drawn off at the bottom, a gauge showed the pressure in the cylinder, the gland nuts were usually tightened with the fingers only, when a wrench was used a spring balance was attached and the turning moment noted; the stroke of the rod was 4.25 inches, the revolutions 200 per minute, giving a piston speed of 141 feet per minute.

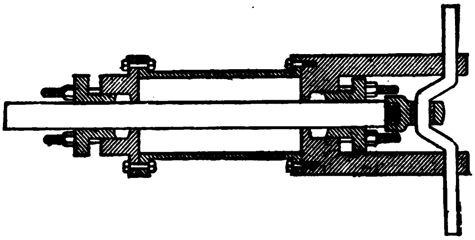

Fig. 5. Bottom. Interior View.

The various packings were fitted according to directions of the makers, the routine of the tests were as follows: The apparatus was first run without packing to determine the friction of the empty machine, the packing was then inserted and steam turned on, the very least pressure

which would prevent leakage was used on the nuts, the packing was then tested under various pressures, each test lasting from 15 to 40 minutes. The nuts were then tightened with the wrench and spring balance to various pressures and other sets of readings taken, cylinder oil was next applied to the rod and the difference in friction noted. These tests were measured by means of a "Flather" recording dynamometer and a "Weber" box gear dynamometer, the readings being taken at short intervals and averaged.

The results of these tests are summed up in the tables (5) and (6); table 5 gives a

TABLE V.

Kind of Pk'ng.	No. of Trials.	Total Time of Run in Min.	Average H. P. Consumed by Each Box.	H. P. Consumed at 50 lbs. Press.	Remarks on Leakage, etc.
1	5	22	.091	.085	Moderate leakage.
2	8	40	.049	.048	Easily adjusted; slight leakage.
3	5	25	.037	.036	Considerable l'kage.
4	5	25	.159	.176	Leaked badly.
5	5	25	.095	.081	Oiling necessary; leaked badly.
6	5	25	.368	.400	Moderate leakage.
7	5	25	.067	.067	Easily adjusted and no leakage.
8	5	25	.082	.082	Very satisfactory; slight leakage.
9	3	15	.200	.182	Moderate leakage.
10	3	..	.275	....	Excessive leakage.
11	5	25	.157	.172	Moderate leakage.
12	5	25	.266	.330	Moderate leakage.
13	5	25	.162	.230	No leakage; oiling necessary.
14	5	25	.176	.276	Moderate leakage; oiling necessary.
15	5	25	.233	.255	Difficult to adjust; no leakage.
16	5	25	.292	.210	Oiling necessary; no leakage.
17	5	25	.128	.084	No leakage.

summary of the results, showing the average horse power absorbed by each packing at various pressures, and, for purposes of comparison, the power at 50 pounds steam pressure.

Table (6), shows the effect of tightening the nuts on the friction of the packing and also the effect of oiling the rod.

TABLE VI.

Kind of Packing.	Horse-power Consumed by Each Box, when Pressure was Applied to Gland Nuts by a Seven-inch Wrench.						H. P. before and after oiling rod.	
	5 Lbs.	8 Lbs.	10 Lbs.	12 Lbs.	14 Lbs.	16 Lbs.	Dry.	Oiled.
1	.120	....	.136					
3	....	....	....	....	....	....	.055	.021
4	....	.248	....	.303	....	.390	.154	.123
5	....	.220						
6	....	.348	.430	....	....	....	.323	.194
7	....	.126	.228	.260	.330	.340	.067	.053
8	....	.363	.500	.535	.520	.533	.533	.236
9	....	.666	....	....	....	....	.666	.636
11	....	.405	.454	....	....	....	.454	.176
12	....	.161	.242	.359	.454	....	.454	.122
13	....	.317	.394	.582				
15	....	.526						
16	....	.327	.860					
17	....	.198	.277	.380				

The general conclusions reached from this series of tests are: *First.*—That the softer rubber and graphite packings consume less power than the harder kinds. *Second.*—That oiling the piston rod will reduce the friction of any packing. *Third.*—That there is almost no limit to the friction loss that can be caused by the injudicious use of the wrench.

FRICTION LOSSES IN MANUFACTURING ESTABLISHMENTS.

But taking a manufacturing plant as a whole by far the greatest amount of friction loss is caused by the shafting being out of line, and by the tension of the belts.

In tranmsitting power from one shaft or piece of machinery to another any degree of tightness of the belts, other than just sufficient to carry the load without slipping, only adds to the friction loss by causing excessive pressure on the bearings, and rendering them more liable to heat.

If the belts are allowed to become hard and dry it is necessary to keep them so tight in order to transmit the power that the per cent. of friction loss increases rapidly, so that it is of the utmost importance that the belts be kept in such condition that they can be run as slack as possible and pull the load without slipping.

The proper care of belting is very important, especially where the work is heavy and the machinery run at a high rate of speed.

As showing the saving in friction loss by proper treatment of the belts, Mr. Chas. F. Chase, Eastern Manager for the Cling-Surface Manufacturing Co., at New York, furnished the author the following data of a test made at the silk mill of Messrs. M. C. Migel & Co., Astoria, N. Y., by Mr. Hubert E. Collins, of New York.

As will be seen by Table 7 there was an increase of from one to five revolutions per minute, and a decrease in the friction load of 19 per cent. in the second test over the first test, at the same time there had been an increase in the engine load of 50 per cent.

*Another very interesting and instructive series of tests made by Professor Benjamin

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*Vol. XVIII. Trans-Am. Soc. Mech. Engs.

TABLE VII.

Speed of Shafts and Friction Load Taken in Silk Mill of M. C. Migel & Co., corner Van Alst and Woolsey avenues, Astoria, N. Y.

Conducted by Hubert E. Collins, expert engineer, New York.

Shafts.	Indicated H.P. 22.1-10. *Speed Sept. 7, 1901. Rev. P. M.	Indicated H.P. 32. †Speed Oct. 24, 1901. Rev. P. M.	Gain Rev. P.M.
Main	160	160	
No. 1 South............	155	158	3
No. 2 South............	155	159	4
No. 3 East.............	158	159	1
No. 3 West	155	159	4
No. 4 East	157	159	2
No. 4 East	154	159	5
No. 1 North............	147	152	5
No. 2 North............	147	150	3
No. 3 North............	151	151	*
	H. P.	H. P.	H. P.
Friction Load	11	9	2

---

*Before Cling-Surface was applied.

†With 50 per cent. more load than when speed was taken September 7, 47 days after Cling-Surface was first applied.

‡Belt is badly laced, which accounts for no increase.

was to determine the percentage of power absorbed by friction of line and counter shafting in a number of manufacturing establishments in Cleveland, Ohio; these tests were made in rolling mills, stamping works, bridge works, screw works, and general machine shops.

The manner in which these tests were made was as follows: Indicator cards were taken at intervals during the day while the shops were in full operation, and again at noon and at night when the machines were not in use, and the belts were on the loose pulleys, by averaging the indicated horse power when running under full load and again when running light, and deducting the latter from the former, a very accurate record of the amount of power absorbed by friction was obtained.

As the result of many tests, among the most reliable of which were those made under the direction of Prof. Benjamin of the Case School of Applied Science, Cleveland, Ohio, it has been found that the friction loss in mill and factory shafting absorbed from 20 to 60 per cent. of the total power developed, and very often a large part of this loss is due solely to over-tight belts.

The lowest percentage of horse power required to drive the shafting and engine occurred in a factory making screws, and amounted to 14.5 per cent. of the total power developed; the next lowest was 39.2 per cent., and the highest was 80.7 per cent., which last figure was obtained in a structural steel works.

The deductions which Prof. Benjamin makes, as the result of these tests are, that large pulleys should be used on counter shafts, and narrow, fast-running belts be used, good oil, and liberally used by means of self-oiling bearings and that the shafting be inspected often and kept in line.

POWER REQUIRED TO OPERATE SHOP TOOLS.

The friction loss in shop tools varies greatly according to their construction, their condition and the work done by them.

A pipe threading machine was found to require 1.2 H. P. when running light at the average speed; the following table shows the power required to cut threads on different size pipe, and the per cent. of power absorbed by friction for each size:

Size of Pipe.	Revo. of Mch. per Minute.	Electrical H. P.	Power absorbed by Friction.
1½-inch	45	2.3	52%
2-inch	32	2.3	52%
3-inch	21	3.1	38%
4-inch	12	5.3	22%

The "American Machinist" describes an interesting series of tests made by Mr. C. W. Pike at the Baldwin Locomotive Works to ascertain the amount of power required to drive shop tools.

In the case of a lathe of 90 inch swing, with two tool heads, both cutting, and turning cast steel driving wheels 5 ft. 7½ in. in diameter, at ½ of a revolution per minute, cut ½″ deep and 1-32″ feed; the power was divided as follows:

Electric motor	1.3	Electrical H.P.
Motor and countershaft	1.43	"
Mot., countershaft and empty mach.	2.1	"
Mot., countershaft and tools cutting	6.38	"

In the case of a planer, driven by an electric motor, with two tool heads, both cutting, planing wrought iron, the power was divided as follows:

Motor	2.4	Electrical H. P.
Motor and countershaft	3.2	"
Motor, countershaft and empty planer on forward travel (20 feet per minute)	3.9	"
Backward motion (80 feet per min.)	4.7	"
With both tools cutting, 1″ deep and ½″ feed	16.7	"

The following interesting and instructive series of tests of the power required to operate shop tools and the loss due to friction were made by Mr. W. A. Carrell, in charge of the Power, Light and Heat department of the Mesta Machine Co. at West Homestead, Pa., near Pittsburg.

The shops are operated entirely by electric

motors, all the large tools are driven by separate motors and the small ones in groups, the shafting in this plant is all installed on I beams, and kept in perfect alignment, thus insuring smooth and quiet running with a low per cent of friction loss.

Power was measured electrically.

154-inch horizontal milling and boring mill, driven by a 7½ H. P. motor.

Empty machine, countershaft and motor, 4 revolutions per minute (friction load)...........	1.1 H. P.
Boring 9-inch hole in cast-iron (rough cut, 4 revolutions per minute).....................	3.6 H. P.
Boring 30-inch hole in cast-iron (rough cut, 4 revolutions per minute).....................	4.0 H. P.
Drilling 1½-inch hole in cast-steel (8 revolutions per minute)..............................	2.0 H. P.
Milling surface with 30-inch milling cutter (⅛-inch cut)..................................	5.0 H. P.

30-foot Pit Lathe, driven by a 10 H. P. motor, facing the rim of a 22-foot fly-wheel, turning 17 feet per minute.

Empty lathe, countershaft and motor (friction load)..	1.7 H. P.
One tool cutting (3-32-inch feed and ⅛-inch cut).	6.8 H. P.
Two tool cutting (3-32-inch feed and ⅛-inch cut..	10.3 H. P.

14-foot boring mill, boring an 84-inch cylinder weighing 50,000 pounds.

Running light, 17½ feet per minute (friction load)	1.5 H. P.
With cylinder casting on the table, same speed..	3.0 H. P.
One tool cutting (⅛-inch feed and ⅛-inch cut)..	5.7 H. P.
Two tool cutting (⅛-inch feed and ⅛-inch cut)..	8.1 H. P.

54-inch planer operated by a 10 H. P. motor. Forward travel, 18 feet per minute. Backward travel, 23 feet per minute.

	Forward.	Backward.
Empty planer (friction load)........	2.3 H. P.	2.8 H. P.
Planer loaded (1,800-lb. casting)......	3.1 H. P.	3.8 H. P.
One tool cutting (1-16″ feed, 3-32″ cut)	5.6 H. P.	
Two tools cutting (1-16″ feed, 3-32″ cut)	7.5 H. P.	

72-inch planer, operated by a 20 H. P. motor, planing a cast iron anvil block weighing 22,000 pounds. Forward travel of planer bed, 17 feet per minute. Backward travel of planer bed, 20 feet per minute.

	Forward.	Backward.
Empty planer (friction load)	4.0 H. P.	5.0 H. P.
Planer loaded (22,000-lb. casting)	9.3 H. P.	12.4 H. P.
One tool cutting (⅛" feed, 3-32" cut)	13.8 H. P.	
Two tools cutting (⅛" feed, 3-32" cut)	17.5 H. P.	

12-foot planer driven by a 30 H. P. motor by means of a counter shaft and friction clutch, planing a 48,000 pound casting, (cast iron). Forward travel of planer bed, 17 feet per minute. Backward travel of planer bed, 22 feet per minute.

	Forward.	Backward.
Empty planer (friction load)	4.7 H. P.	5.5 H. P.
Loaded planer (22,000-lb. casting)	11.0 H. P.	14.6 H. P.
One tool cutting (⅛" feed, 3-32" cut)	15.6 H. P.	
Two tools cutting (⅛" feed, 3-32" cut)	20.3 H. P.	

The power ran high at the point of reversal of the planer bed, showing 30 horse power for a few seconds, and then settling back to the power shown above, the machine was working on an 8 foot stroke and the time between the reversals was not the best for a test of this kind.

72-inch engine lathe, turning a cast steel shaft 23 inches in diameter, (rough cut), rate of surface travel, 16 feet per minute.

Roll lathe, turning a chilled cast iron roll, 36 inches in diameter, speed 45 feet per minute.

Motor and empty lathe (friction load)	1.1 H. P.
Motor and shaft in the lathe	2.3 H. P.
Two tools cutting (⅛" feed, 5-32" cut)	6.8 H. P.

Roll lathe, turning a cast steel roll, 42 inch in diameter, speed 90 feet per minute.

One 5-inch tool, finishing (1-64" cut)	2.0 H. P.
Two 5-inch tools, finishing (1-64" cut)	3.2 H. P.
One 3-inch tool, roughing (1-16" cut)	3.5 H. P.
Two 3-inch tools, roughing (1-16" cut)	6.5 H. P.

In the two last tests the motor, counter shaft and the lathe required 1.3 H. P. to operate it at the required speed.

THEORY OF LUBRICATION.

Lubrication as it is considered in mechanics is the application or introduction of a smooth fluid substance, preferably an oil, between two hard moving surfaces that will keep them from coming in direct contact.

Unless the surfaces are kept apart by some medium the asperities and irregularities which exist on all surfaces no matter how hard or smooth, will interlock, and the friction caused in tearing them apart and wearing them down will generate heat.

The action of a lubricant is to flow between the close-fitting surfaces, filling up the interstices and covering up the high spots, acting as a cushion and taking up whatever heat may be generated and carrying it off instead of allowing it to be absorbed by the wearing surfaces.

To do this properly, a lubricant should have certain properties, it should be of a fluid nature so that it will flow readily between surfaces that are close-fitting and under heavy pressure. It should possess a certain amount of cohesiveness, or viscosity, as it is usually called.

By cohesiveness is meant the property of a substance to cling to its own particles. Viscosity is understood as the degree of fluidity that an oil possesses, or the resistance opposed by its particles to their separation.

Oil should have good adhesive properties in order that it will cling well to metallic surfaces. By ad-

hesion is meant the property of a substance to cling to other than its own particles.

It should be high in flash test in order that whatever heat it is subjected to will not cause it to give off an inflammable vapor. It should have a cold test of such degree that it will remain fluid at low temperatures.

The above requirements will be found embodied to the greatest degree in the various kinds of vegetable, animal and petroleum oils.

The first oils used in the lubrication of machinery were vegetable oils, such as castor oil, palm oil, and olive oil; and animal oil such as lard, neatsfoot, tallow and sperm oils.

All these oils, while in many respects excellent lubricants are not now used to any extent since the introduction of petroleum or mineral oils, for the following reasons:—*First.*—On account of their higher price as compared with petroleum oils. In recent years the processes of refining petroleum have been brought to such a state of perfection that they have almost entirely driven the animal and vegetable oils from the market as lubricants for machinery. *Second.*—Being of organic origin they absorb oxygen from the atmosphere, and, in time, become rancid, thick and gummy. These oils are of very poor cold test, congealing at a comparatively high temperature, thus making them inconvenient for use in cold weather.

Petroleum oils have many advantages as lubricants over animal or vegetable oils. *First,* is their cheapness. *Second,* being of non organic origin they do not change their condition, do not become rancid, thick or gummy by constant exposure to the air, and have no corrosive action on metals. *Third,* by what is known as fractional distillation they can be separated into a great many different grades, from the lightest spindle oils to the dense heavy cylinder oils. *Fourth*, they are of lower cold test and there is not the liability of spontaneous combustion as with animal oils.

The engineer in charge of a plant will find on the market a wide range of petroleum lubricants to choose from to meet the various conditions which will arise in the proper lubrication of his machinery.

The conditions which produce the greatest differences in ordinary lubrication are the nature and quality of the lubricant, the nature and condition of the wearing surfaces, the speed and pressure and the temperature.

Variations of friction of lubricated surfaces occur with every change of condition of either the bearing or journal surfaces, or of the lubricant applied to them.

The ordinary facilities of the engine room do not usually afford means to make elaborate tests of the coefficient of friction of various oils, nor would such tests be of any practical value to an engineer, as they can only be made with any degree of accuracy on expensive testing machines built expressly for this purpose which are very little used except in the laboratories of the technical schools and the testing rooms of a few of the large railroad companies and manufacturers of oils.

But an engineer can often make valuable comparative tests of different grades of oil on the ordinary machinery of the engine room, for instance, a difference between two oils of several degrees in the temperature of a bearing of an engine or a dynamo may be detected by means of a thermometer placed in the bearing with the bulb resting on the shaft or immersed in the oil chamber.

In tests of this kind care must be taken that the rate of oil feed, the belt tension, the pressure on the bearings and the speed remain constant; an allowance should also be made for any difference in the temperature of the room during the tests.

Some day, engine builders will equip the main bearings of their engines with thermometers so that the temperature can be noted, the engineer will then be able to see at a glance whether the temperature is above the normal or not, in the same way as he notes the temperature of his feed water by means of a thermometer in the boiler feed pipe; of course, an engine bearing from lack of oil, stoppage of the oil cups or other cause can become overheated to such a degree as to ignite the oil in some particular spot before the rise in temperature would be indicated on a thermometer a few inches away.

But a thermometer in a bearing would indicate from day to day any difference in the condition of either the lubricant or the bearing—for instance, an engineer on taking up the lost motion of a main bearing notices that the temperature rises 10 to 20 degrees above what it had previously been, this warns him that this bearing must be carefully watched to see that it does not get too hot.

One of the essential points in lubrication is that the lubricant be made to reach every part of the contact surfaces, and in connection with lubrication one may assume an oil to have the nature of a mass of globular molecules or atoms, which roll on each other and the wearing surfaces and are carried or flow between the close-fitting surfaces and form an elastic coating to the metal which becomes thinner as the pressure increases or the temperature rises, and thicker as the pressure decreases or the temperature falls, and absorbing whatever heat may be generated and carrying it off.

The best lubricant for a bearing under normal conditions may not do so well when heating commences, a thick viscous oil which under ordinary conditions on high speed machinery would be comparatively wasteful of power is often an excellent lubricant for a hot bearing, and for the following reason, an engineer on finding a bearing heating up will apply the ordinary oil freely and at the same time loosen up the bolts so as to allow for increased expansion and free flow of oil, if the heating continues, and the engine or machinery must be kept in operation at all hazards, he will turn to his cylinder oil, apply it freely, and often with good results. The reason of this is that the cylinder oil, owing to its high fire test, (from 550 to 600) became thin and limpid without burning, and flowed freely between the close-fitting surfaces and kept them apart, and at the same time, absorbed the heat that would otherwise have gone into the metal and carried it away, while the engine oil, being of lower flash test vaporized, and if the bearing got hot enough, caught fire.

The theory of a heating bearing is as follows: If for any reason the oil is prevented from reaching every part of a bearing, the surfaces will come in direct metallic contact, excessive friction is set up and heat is generated; if the pressure be not great and the bearing area ample the heat may be absorbed by the metal and radiated out into the air and nothing serious occur. But if the pressure is heavy and the speed high the heat may be generated faster than the metal can carry it away, the original dry spot may not have been over $\frac{1}{8}$ or $\frac{1}{4}$ of a square inch in area but sufficient heat may have been generated at this point to cause the adjacent oil to evaporate and shrink away, thus increasing the area of dry surface, as the heat increases the metal expands causing the surfaces to fit tighter and thus creating more friction until the temperature reaches such a point that it ignites and burns. As a good engine oil will have a flash test of about 400 degrees the temperature of the metal must rise above that in order to ignite the oil.

TESTING OF OILS.

Lubricating oils are graded and classified according to their properties which are determined by certain tests, these are very simple and easily made, and every oilhouse or engine room should be provided with the few cheap and simple instruments necessary to test the oil and should keep a record of these tests. While these tests will not indicate the friction reducing value of an oil, yet, where the oils are bought with the understanding that they must conform to certain specifications as regards gravity, viscosity, etc., any variation from this standard will be indicated by the use of those instruments.

The tests usually made to determine the properties of an oil are Gravity, Viscosity, Flash and Fire test, Cold test, Evaporation test, and how to determine the presence of animal or vegetable oil in a compounded oil.

VISCOSITY.

In lubricating oil, and especially in cylinder oil, the viscosity or body as it is sometimes called, is a very important property.

By viscosity is understood the degree of fluidity that an oil possesses, or the resistance opposed by its particles or atoms to their separation, the viscosity of an oil is not proportional to its specific gravity, but to its cohesiveness or internal friction, and will vary with the temperature.

The viscosity of an oil is determined by means of an instrument called a viscosimeter; there are several kinds of viscosimeters and the principle on which most of them operate is the number of seconds that a given quantity of oil at a certain temperature will flow through an orifice.

It is to be regretted that there is no recognized standard instrument, or established method of taking the viscosity of fluids, and when one states that an oil has a certain viscosity, it conveys no meaning unless the name and make of the instrument, the amount of oil tested and the temperature are given.

In determining the viscosity of oils it is a good plan to take engine, dynamo and machine oil at 70 deg. Fahr, or normal room temperature and again at 120 deg. or the temperature of a bearing that is running quite warm, it will often be found that two samples of oil that will have the same viscosity at 70 deg. will vary greatly at a higher temperature.

With cylinder and other dense oils the viscosity can be taken at say 100, 200 and at 300 degrees, but when testing at temperatures over 212 deg. oil instead of water should be used in the outer receptacle.

THE SCOTT VISCOSIMETER.

One of the best and simplest instruments for determining the viscosity of an oil or other liquid is what is called the "Scott" viscosimeter, as will be seen by the cuts, Fig. 6. It consists of a metal cup with an orifice at the bottom which is kept closed by a ball valve on a rod which extends up through the cover, this orifice can be opened to allow the oil to run out by pressing down on the lever on the cover of the cup, the oil cup rests in an outer receptacle which is kept filled with water, this outer receptacle stands on a tripod over a gas jet or an alcohol lamp by means of which the water and oil can be brought to the desired temperature.

To operate this instrument, first fill the oil cup with 200 cubic centimeters of the oil to be tested, fill the water bath with water, place an accurate thermometer in the oil, and if testing an engine, dynamo or machine oil bring the temperature to exactly 70 degrees Fahr. if testing cylinder oil, bring the temperature to 210 degrees or just below the boiling point of water.

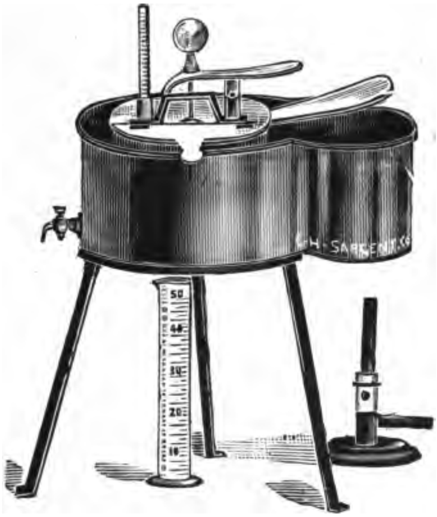

Fig. 6. The Scott Viscosimeter.

When the temperature has been brought to the desired point and kept at that for two or three minutes place a 50 cubic centimeter flask under the oil outlet and with a stop watch in one hand start the oil to running by pressing on the lever with the other, and at the same instant starting the watch; when the oil reaches the 50 C. C. mark on the flask stop the watch and release the lever, the number of seconds that are rquired for 50 C. C. of the oil to flow into the glass is the "time viscosity."

Each instrument is marked with the "water figure," or water viscosity, that is, the number of seconds required for 50 C. C. of distilled water at 60 deg. Fahr. to run out, is called the "water" figure" of that instrument.

The time viscosity divided by the water figure will give the "specific viscosity": For instance, we find that the time viscosity of a sample of oil is 85 seconds, the water figure being 10, then 85÷10=8.5=Specific Viscosity, consequently the oil is 8.5 times thicker than water at 60 degrees, Fahr.

In very accurate scientific work it is sometimes necessary to take into account the effect of the specific gravity on viscosity, in which case we take what is called the "gravimetric viscosity"; this is determined by simply dividing the specific viscosity of the oil by its specific gravity.

For instance, the specific viscosity of a heavy engine oil is found to be 8.5 and the specific gravity .8945, then 8.5÷.8945=9.502=gravimetric viscosity.

But for all practical purposes the specific viscosity is all that need be determined.

THE TAGLIABUE VISCOSIMETER.

Another well known and very accurate instrument is the Tagliabue viscosimeter shown in Fig. 7, which consists of copper boiler provided with a safety valve, and a water gauge, an alcohol lamp with four burners is provided to heat the water in the boiler, above the boiler and connected to it by the stop-cock B is the heater in which the oil receptacle stands; the steam on being generated in the boiler passes

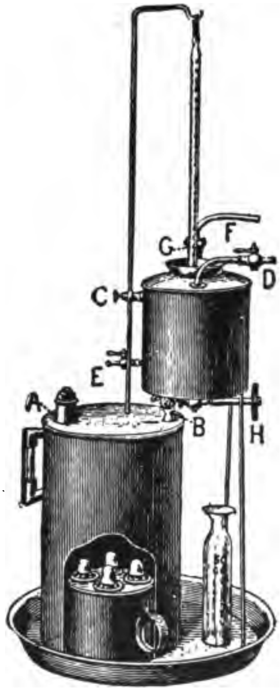

Fig. 7. Tagliabue Viscosimeter.

through the stop-cock B into the heater where it imparts its heat to the oil.

Its operation is as follows: For testing cylinder oil or other dense oils, first fill the boiler with water through the opening (A), the gauge glass will indicate when the boiler is full, see that the stop-cock B is open which makes a direct connection to the upper vessel or heater.

Fill the inner chamber with the oil to be tested, suspend the thermometer by means of the wire holder so that the bulb will be about ¼ of an inch above the bottom of the oil.

Strain and pour into the oil chamber 70 cubic centimeters of the oil to be tested; close stop-cocks D and E, attach the rubber hose F to G and immerse the end of it in a vessel of water which will prevent too great loss of steam.

Light the alcohol lamp and place it under the boiler and if testing cylinder oil, screw the steel nipple marked 212 onto the stop-cock H; while the oil is heating it should be stirred so as to obtain a uniform temperature.

When the temperature reaches 212 degrees, place the 50 c. c. glass under the oil discharge nipple so that the oil in running will strike the side of the glass and prevent air bubbles.

Open the valve H and at the same instant start the stop-watch, which is sent with each instrument, the instant that the oil reaches the 50 c. c. mark on the neck of the glass stop the watch.

The number of seconds that it takes for 50 c. c. of the oil to run through, multiplied by 2 will be the viscosity of the oil.

For instance, if 50 c. c. of oil ran through in 108 seconds the viscosity would be 108x2=216.

To take the viscosity of engine, machinery, dynamo and other fluid oils, use the steel nipple marked 70, close the stop-cock B, shutting off connection between the boiler and heater, also close the stop-cock E.

Fill the upper vessel through G with water at as near 70 degrees as possible, and have the oil at the same temperature, should the thermometer show higher or lower than 70 degrees pour cold or warm water into the vessel till the exact temperature is obtained, then proceed as with cylinder oil.

THE DOOLITTLE TORSION VISCOSIMETER.

Another make of viscosimeter and one which differs materially and possesses certain advantages over other instruments, is what is known as the Doolittle Viscosimeter, invented by Mr. O. S. Doolittle, chemist for the Philadelphia and Reading Railroad Co.

This viscosimeter is free from some objections which exist in most other makes, one of which is that it is not based on the principle of allowing the oil to flow through an orifice, it is not necessary to strain the oil before testing, the viscosity of oils can be taken at temperatures above that of the boiling point of water, and any number of tests can be made with the same sample without re-handling.

Cylinder and valve oils are used to lubricate the wearing surfaces at temperatures due to the temperature of the steam, which is usually from 300 to 400 degrees and it is sometimes important to know the relative viscosities of oils at these temperatures, with this instrument the viscosity can be taken at temperatures as high as the oil can be heated.

Very often an oil which will show a higher viscosity than another at a low temperature will be quite low in viscosity at high temperature.

The construction of this instrument is as follows: See Fig. 8. The oil chamber which contains the oil that is to be tested is enclosed in an outer receptacle, if engine oil or other thin fluid oils are to be tested the outer chamber is to be filled with water; if testing cylinder oils, the outer chamber should be filled with some high fire test oil, beneath which is placed an alcohol lamp so as to heat the oil to the desired temperature.

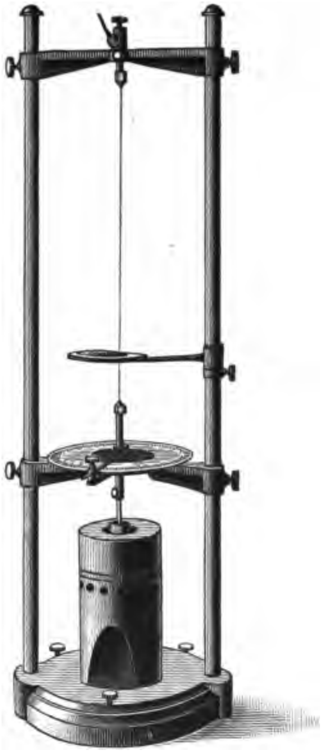

Fig. 8. The Doolittle Torsion Viscosimeter.

Suspended from the cross-bar is a steel wire at the lower end of which and attached to the stem is a metal disc or circle graduated to 360 degrees; above the disc and attached to the upright is a magnifying glass to be used in reading the disc; below the stem is a metal cylinder about 2½ long and 1½ inches in diameter.

This cylinder swings freely in the oil chamber and is immersed in the oil to be tested.

The operation of this viscosimeter is as follows: The oil to be tested is poured into the inner receptacle till the metal cylinder is immersed to the depth of about ¼ of an inch; the temperature of the oil is then raised to the desired point by means of the lamp.

The index should point to the zero mark on the graduated disc, then by means of the milled head or nut at the top twist the wire one whole turn or revolution, then by means of the cam lever raise the disc from its support, and the disc and cylinder will revolve back towards its original position, due to the torsion of the wire. The amount of retardation due to the cylinder swinging in the oil determines the viscosity of the oil.

If there were no resistance to be overcome the disc would swing back to the zero mark or beyond, but as the cylinder is immersed in the oil, the oil has a retarding effect and the disc will not swing the full distance, and the more viscid the oil the greater the retardation will be.

The viscosity is taken as the number of degrees between the first and third swing of the disc, the second or backward swing is not considered.

For instance, the oil is brought up to the desired temperature which is usually 70 degrees, for engine oil and 210 degrees for cylinder oil, the disc when released swings to the right 340 degrees, then swings back to the left and again swings to the right, this time to 275 degrees.

The difference between 340 degrees and 275 or 65 degrees indicates the viscosity of the oil.

In order to eliminate chances of error, make another test by allowing the disc to swing to the left instead of the right, if the wire is in good order the results should be the same, but if there is a difference the mean of two trials should be taken as the viscosity.

Some users of the Doolittle viscosimeter take these readings as sufficiently accurate for practical purposes, but Mr. Doolittle recommends that the viscosity of an oil be expressed in the number of grams of pure cane sugar contained in 100 cubic centimeters of the syrup at 60 degrees Fahr., and each instrument is standardized against pure sugar solutions.

In most makes of viscosimeters the oil flowing through an orifice has a very appreciable error due to the specific gravity of the oil.

Mr. Doolittle in making some tests on the torsion viscosimeter found that a certain oil of 0.9 specific gravity had a viscosity of 86.4, he then made a sugar solution of exactly the same viscosity and having a specific gravity of 1.4.

He then run them through a Saybolt viscosimeter, the oil ran through in 35¼ seconds, while the sugar solution only took 30¼ seconds; thus showing that the difference in the specific gravity caused an error of 5 seconds by forcing the syrup through faster than the oil.

To still further prove that the presence of this error was due to the difference in the specific gravity he determined the viscosity of an oil having a specific gravity of 0.9 to be 35¼ seconds, he then made a sugar solution which gave the same reading on this instrument, which showed a specific gravity of 1.48.

The viscosity of these two liquids was then taken on the Doolittle torsion viscosimeter and it was found that the oil showed a viscosity of 86.8 degrees, while that of the syrup showed 91.8 degrees, again making a difference of 5 degrees. This showed that it was necessary to make a syrup of decidedly higher viscosity than the oil in order to overcome the error due to the difference in specific gravity and show the same reading on the Saybolt viscosimeter.

PIPETTE VISCOSIMETER.

Another method of determining the viscosity of oils, and one which is accurate enough for ordinary engine room use besides being inexpensive is known as the Pennsylvania Railroad Co.'s method and consists of a long-bulb pipette graduated so as to contain exactly 100 C. C. from a mark at the bottom to a mark at the top of the bulb, and is generally known as the "Dudley Viscosimeter," see Fig. 9. The size of the aperture at the bottom of the pipette is so made that 100 C. C. of water at 100 deg. Fahr. will run out in 34 seconds.

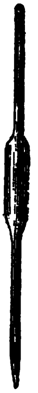

Fig. 9. Pipette Viscosimeter.

The oil to be tested is heated to the required temperature (about 70 degrees for engine oil and 200 degrees for cylinder oil), and is then emptied in or drawn up into the pipette to the upper mark. The number of seconds that it takes for the oil to run from the top mark to the bottom mark indicates its viscosity.

The Dudley viscosimeter can be arranged in a water bath so as to maintain a constant temperature by means of an alcohol lamp or gas jet.

FLASH AND FIRE TEST.

The flash test and fire or burning test of an oil indicates its ability to withstand heat. *The flashing point of an oil is the temperature to which it must be heated to cause it to give off a vapor which will ignite when mixed with air and exposed to a flame; the fire test or burning test is the temperature at which the oil itself ignites and continues to burn.*

To take the flash and fire test of an oil is a very simple matter; all that is necessary is a metal cup (an ordinary enamelled ware drinking cup will do), an alcohol lamp or small gas jet, and a thermometer that will register to 650 or 700 degrees Fahr.; there are, however, a number of appliances especially made for this work. Tagliabues open tester is the one most commonly used for testing lubricating oils, while his closed tester is used for burning oils.

To take the flash test of an oil fill the cup to within ¼ inch of the top with the oil to be tested, place it over the lamp or jet and hang the thermometer in the oil so that the oil stands about a ½ inch above the mercury bulb; the oil should be heated slowly and the flame must not be too large nor be too close to the cup and must be kept out of draughts; the rise in temperature after the first 100 degrees should be at a rate of not to exceed 10 or 15 degrees per minute until it reaches 250 or 300 degrees, when the flame should be adjusted to heat more slowly.

In testing engine oils, the flashing torch which should consist of a piece of waxed twine or a very small gas jet, should be lighted and passed over the surface of the oil two or three times a minute after the temperature reaches 250 or 300 degrees, and with cylinder oils after the temperature reaches 400 or 450 degrees.

The flash point will be noted by the presence of a faint puff of blue flame; if the heating be continued till the surface of the oil ignites and continues to burn the temperature at which it ignites will be the burning point or fire test.

The fire test will usually be from 45 to 75 degrees higher than the flash test.

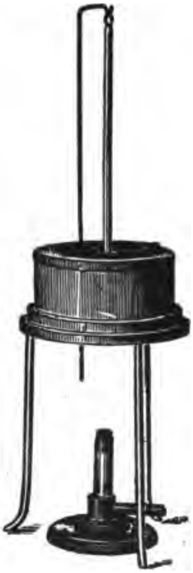

Fig. 10. Instrument for Taking Flash and Fire Test.

SPECIFIC GRAVITY.

The specific gravity of an oil or other substance is defined as the ratio between its weight and that of an equal volume of water.

A cubic foot of pure distilled water at a temperature of 39.2 deg. Fahr. or its point of greatest density weighs 62.42 pounds but in calculations it is usually taken as weighing 62.5 pounds.

To determine the specific gravity of a sample of oil divide its weight by an equal volume of water, or, to be more accurate, divide the weight of a cubic foot of the oil by 62.5, for instance, lard oil weighs 57.34 pounds per cubic foot, then

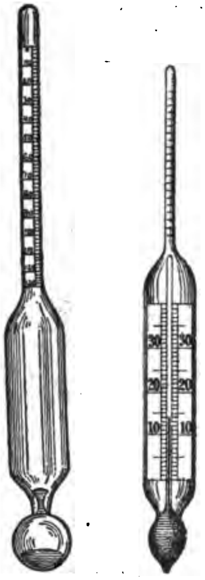

Fig. 11. Baume Hydrometers.

$$\text{Specific Gravity} = \frac{57.34}{62.5} .9175$$

The gravity of oil in commercial work is usually ascertained by means of a Baume′ Hydrometer, see Fig. 11, which consists of a glass tube marked in degrees somewhat similar to an ordinary thermometer and having a bulb at the lower end weighted so that when immersed in water it will sink to the point marked 10 and rise above or sink below that mark according to the density or weight of the liquid in which it is immersed; but where the oils to be tested only range from 20 to 40 degrees, Baume′ hydrometers graduated for this range can be procured. In taking the gravity with a Baume′ hydrometer one must be careful to note the temperature of the oil, and in ordinary commercial work it is customary for every 10 degrees above 60 Fahr. to subtract one degree from the hydrometer reading, and for every 10 degrees less than 60 Fhr. add one degree to the hydrometer reading; for instance, if the temperature of the oil were 70 Fahr. and the hydrometer stood at 28 the gravity would be 27, but if the temperature were 50 Fahr. and the hydrometer stood at 28 the correct reading would be 29.

When testing a dense oil it should be warmed till it is thin enough so that the hydrometer will rise or sink freely in it.

But where greater accuracy is desired Table 8 should be used which shows the difference in the Baume′ readings at different temperatures. For instance, an oil in which at 70 degrees Fahr. the hydrometer registers 25.3, the correct reading for 60 degrees Fahr. would be 26 B′.

TABLE VIII.

Table 8.—Showing the Baumé readings at various temperatures, corrected for 60 deg. Fahr.

Indication on Hydrometer.		20°F.	30°	50°	60°	62°	64°	66°	68°	70°	72°	74°	76°	78°
20°	B.	22.5	21.8	21.1	20.	19.9	19.8	19.6	19.5	19.4	19.3	19.2	19.1	19
22	B.	24.6	23.9	23.2	22.	21.9	21.7	21.6	21.5	21.4	21.3	21.1	21.	20.9
24	B.	26.7	26.	25.2	24.	23.9	23.7	23.6	23.5	23.4	23.2	23.1	23.	22.9
26	B.	28.8	28.	27.3	26.	25.9	25.7	25.6	25.5	25.3	25.2	25.1	25.	24.8
28	B.	30.9	30.1	29.3	28.	27.9	27.7	27.6	27.5	27.3	27.2	27.1	26.9	26.8
30	B.	32.5	32.2	31.4	30.	29.9	29.7	29.6	29.5	29.3	29.2	29.	28.9	28.8
32	B.	35.	34.2	33.5	32.	31.9	31.7	31.6	31.4	31.3	31.2	31.	30.9	30.7
34	B.	37.1	36.3	35.5	34.	33.8	33.7	33.5	33.4	33.3	33.1	33.	32.8	32.7
36	B.	39.2	38.4	37.6	36.	35.8	35.7	35.5	35.4	35.2	35.1	34.9	34.8	34.6
38	B.	41.3	40.4	39.6	38.	37.8	37.7	37.5	37.4	37.2	37.1	36.9	36.8	36.6
40	B.	43.4	42.5	41.6	40.	39.8	39.7	39.5	39.4	39.2	39.	38.9	38.7	38.5
44	B.	47.6	46.7	45.7	44.	43.8	43.6	43.5	43.3	43.1	43.	42.8	42.6	42.5
50	B.	54.1	53.0	52.0	50.	49.8	49.6	49.4	49.2	49.1	48.9	48.7	48.5	48.3
55	B.	59.5	58.3	57.1	55.	54.8	54.6	54.4	54.2	54.	53.8	53.6	53.4	53.2
60	B.	64.9	63.7	62.3	60.	59.8	59.6	59.3	59.1	58.9	58.7	58.5	58.2	58.
70	B.	75.9	74.3	72.7	70.	69.7	69.5	69.2	69.	68.7	68.4	68.2	68.	67.7

Table 9 shows the relation of the Baume' gr. to the specific gravity, the weight per gallon and the weight per cubic foot.

TABLE IX.

Table showing Baumé Sp. Gr., pounds per gallon and pounds per cubic foot, and their relation to each other:

Baumé.	Sp. gr.	Lbs. per gal.	Lbs. per cu. ft.
10	1.000	8.33	62.50
11	0.9929	8.27	62.05
12	0.9859	8.21	61.61
13	0.9790	8.16	61.18
14	0.9722	8.10	60.76
15	0.9655	8.04	60.29
16	0.9589	7.99	59.90
17	0.9523	7.93	59.51
18	0.9955	7.88	59.11
19	0.9395	7.83	58.81
20	0.9333	7.78	58.33
21	0.9271	7.72	57.94
22	0.9210	7.67	57.56
23	0.9150	7.62	57.18
24	0.9090	7.57	56.81
25	0.9032	7.53	56.41
26	0.8574	7.48	56.08
27	0.8917	7.43	55.63
28	0.8860	7.38	55.27
29	0.8805	7.34	55.03
30	0.8750	7.29	54.68
31	0.8695	7.24	54.34
32	0.8641	7.20	54.00
33	0.8588	7.15	53.67
34	0.8536	7.11	53.35
35	0.8484	7.07	53.02
36	0.8433	7.03	52.70
37	0.8383	6.98	52.39
38	0.8333	6.94	52.07
39	0.8284	6.90	51.77

Mr. Augustus Gill in his work on "Oil Analysis" gives the following formula for determining the specific gravity of an oil from the Baume' reading:

$$\text{Sp. gr.} = \frac{140}{130 + B'}$$

B' representing the Baume' reading of the hydrometer. For instance, it is desired to ascertain the specific gravity of an oil of 28 gravity Baume', then

$$\frac{140}{130 + 28} = 0.8861 \text{ sp. gr.}$$

COLD TEST.

The cold test of an oil is the point at which it congeals, or, to be more accurate, with a transparent oil it is the temperature at which it begins to get cloudy or opaque, but with a dense viscid oil such as a cylinder oil it is the temperature at which it will just commence to flow after being frozen.

The cold test or lack of cold test is no indication of its lubricating value, but it is very essential that oil for use on machinery and engines which are exposed to the weather should be of good cold test so that it will flow freely in cold weather.

To take the cold test of a sample of engine oil insert a thermometer in a bottle of the oil and place the bottle in a mixture of cracked ice and salt, or if in a refrigerating plant immerse the bottle in the brine tank, or arrange a wooden pail or small tub with a coil of quarter-inch pipe from an amonia drum or to the compression part of the system in the bottom of the tub and fill the tub with enough ordinary burning oil or kerosine to immerse the bottles to the neck, place the bottles of oil in the tub, turn on the ammonia and note the temperature at which the oil congeals.

ELASTICITY OR RESILIENCY.

There is another property which has been attributed to lubricating oils, which cannot be measured by an instrument, and which, it is supposed, bears no relation to its other properties, and .which may be termed its elasticity, or resiliency.

It is generally assumed that an atom of oil is spherical in shape, and if the atoms are lacking in elasticity or resiliency they will flatten under pressure and not return to their original form, like lead shot that has been passed between a pair of steel rollers, while if the oil has these properties to a high degree, the atoms or molecules will, after being subjected to pressure between a journal and its bearing, act like rubber balls and instantly assume their original shape.

But this theory is, however, merely an assumption and definite proof is lacking of its actual existence.

EVAPORATION TEST.

In some classes of machinery, especially that devoted to the manufacture of textile fabrics the percentage of volatile matter in an oil is a very important factor both as regards its safety and its lubricating value; if it contain any great amount of volatile properties the frictional heat will liberate it at the ordinary working temperature of the bearings; this may not work any serious results beyond the fact that the portion of the oil that is thus liberated has been bought and paid for by the gallon and is so much loss, but in spinning and weaving machinery the lower ends of the spindles on which the bobbins are placed are immersed in a bath of oil, and it is very essential that the oil for this purpose be not only of high lubricating value but thin and limpid, in order that it will not have a retarding effect on the spindles and thus increase the frictional resistance.

If any appreciable amount of volatile matter is given off it will increase the density of the oil and therefore increase the frictional resistance.

To test for the per centage of evaporation pour a small quantity of the oil in a shallow dish, weigh it carefully in a chemist's or other sensitive scales and expose it to a temperature of 140 or 150 degrees for 10 or 12 hours, again weigh the sample and the percentage of evaporation will be indicated by the difference in weight.

TESTS FOR ANIMAL OILS.

If a petroleum oil has been compounded with animal oil such as lard oil, sperm oil, tallow or neatsfoot oil the fact can be usually detected by the sense of smell.

Each of these oils have a distinctive odor which can be easily distinguished by heating a small portion or by pouring a few drops in the palm of one hand and rubbing briskly with the fingers of the other for a moment till the oil gets warm and then holding it close to the nose and smelling it.

Another method is to pour a little of the oil into a bottle with about an equal quantity of borax or caustic soda solution, shake the two well together, if any animal oil be present it will form a yellow or whiteish emulsion, but if the oil be of pure petroleum it will remain clear and separate freely from the solution.

THURSTON'S OIL TESTING MACHINE.

A number of machines have been devised to determine the comparative lubricating value of different oils, the anti-friction value of different bearing metals, the coefficient of friction, etc., under as near actual running conditions as it is possible to obtain on a testing machine, and many valuable tests and experiments have been made on them.

One of the best and most practical oil testing machines is the Thurston Standard Railway Oil Testing Machine, the invention of Dr. Thurston, Director of Sibley College, Cornell University, This machine has been especially designed to provide the means of a reliable and systematic investigation of the different oils in use in railway service.

This machine (See Fig. 12) consists of a suitable housing or pedestal supporting a horizontal shaft, one end of which is formed to the exact size and shape of an ordinary car journal, the other end of the shaft has a cone pulley so as to run it at different speeds; a square case in which the bearings are placed, surrounds the journal, and under the case is a tube that contains a helical spring so arranged that any desired pressure up to 9,000 pounds can be put on the bearings, the spring can be tightened with a wrench and the pressure will be indicated by an index on the side of the tube; a thermometer registering from 40 degrees to 350 degrees is fitted in the top brass so as to indicate the amount of the frictional heat developed during a test.

The bearings are of phosphor bronze and provided with a cored space for water circulation so as to absorb the frictional heat. The brasses can also be provided with thin accurately-fitted liners of different kinds of bearing metals that

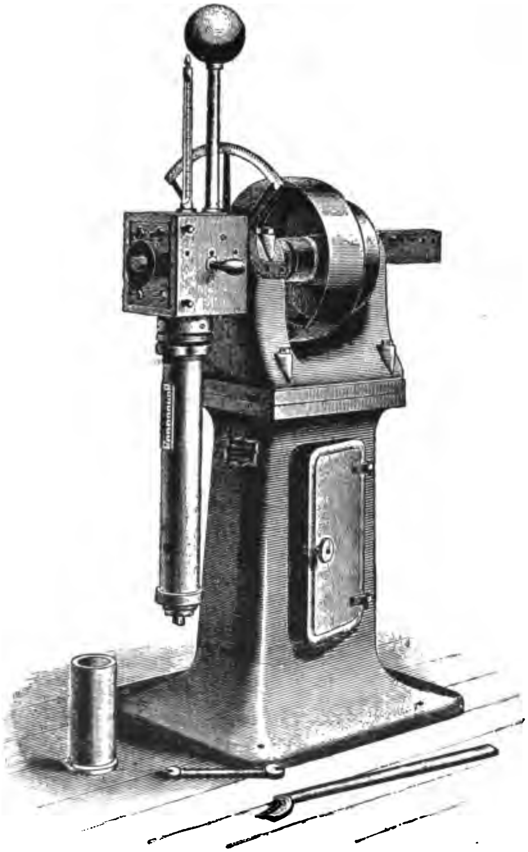

Fig. 12. Thurston's Railway Oil Testing Machine.

are to be tested, so that they may be weighed before and after a test and the frictional wear determined, or ordinary car brasses can be used and the journal run at the same rates of speed that would occur in actual railway practice.

The operation of the machine is as follows: Until the spring is tightened up, the brasses together with the pendulum tube containing the spring, will swing freely on the journal, but when a test is to be made oil is applied to the wearing surfaces in a given quantity, the spring is tightened to the desired pressure and the temperature noted, the machine set running at the desired number of revolutions per minute, which will be indicated by the revolution counter at the back of the machine; as the speed or pressure is increased the friction causes the pendulum to swing to one side, and the angle that it will assume is indicated by the index pointer on the graduated arc at the back of the case and is a measure of the amount of the friction.

In testing oils or bearing metals it is customary either to run the machine at a given rate of speed and note the length of time that it takes for the temperature to reach a certain point, or to run each test a certain number of minutes and note the temperature.

For instance, it is desired to determine the lubricating value of two oils; a pressure of, say 500 pounds per square inch of the projected area of the journal is put on by tightening the spring, the temperature as shown by the thermometer before starting is 70 degrees Fahr. and five drops per minute are fed to the bearing; it required a run of 20 minutes to raise the temperature 300 degrees, and the angle of friction as shown by the index pointer was 22, while with another oil under the same conditions it required a run of 30 minutes to reach the same temperature and the angle of friction was only 18. This would indicate that if the same difference held good through several different tests including changes of pressure and speed that the second oil was the better lubricant, or that of two or more oils tested under the same conditions, the one running continuously at the lowest temperature will naturally be the best lubricant, while it will sometimes be noted that the co-efficient of friction will decrease as the temperature rises, yet for practical work the oil that will keep the bearings the coolest is the most economical.

When testing the anti-friction value of different metals the machine is started without oil on the surfaces at a certain rate of speed and pressure, the metal showing the least angle of friction, the lowest temperature and smallest per cent. of metallic wear will be the best.

CYLINDER AND VALVE LUBRICATION.

In the lubrication of the interior wearing surfaces of the valves and cylinders of steam engines conditions will be met which are altogether different from those encountered in the lubrication of bearings and journals.

In the latter case, the working and comparing of one oil with another, and the results obtained, can be easily determined by noting the changes of temperature, etc., but in internal lubrication the conditions are altogether different.

In the case of journals and bearings, the oil can be applied directly to the surface tobe lubricated, in cylinder lubrication one must depend upon the flow of steam to convey the oil to the parts or wearing surfaces requiring lubrication.

The points that govern the conditions of interior lubrication are: The condition of the surfaces, the steam pressure, the amount of moisture in the steam, the piston speed, weight and fit of the moving parts, and the make or type of the engine.

An automatic cut-off engine with balanced or piston valves will usually require less oil than an engine with a heavy unbalanced valve.

A large cylinder whose piston is supported by a "tail-rod" is more easily lubricated than one whose heavy piston drags back and forth over the bottom of the cylinder.

The dryness of the steam is a very important factor in cylinder lubrication, engines which take their steam supply from foaming or priming boilers, or through long uncovered steam pipes usually require more oil than an engine supplied with dry steam.

Wet steam is the greatest cause for complaint in the lubrication of valves and cylinder surfaces with which an engineer has to contend, but some grades of cylinder oil will give better results in connection with wet steam than others; they will stick to the moist surfaces better.

An engineer who desires to secure the best results and reduce the friction loss to the minimum must study the various conditions which exist in the machinery in his charge; always bearing in mind that friction costs more than oil, and that a small quantity of good oil properly used will be more economical than any quantity of poor oil.

In the early days of the steam engine, the question of cylinder lubrication was not a matter of very much importance; the lubricant most generally used was tallow, and the appliance for feeding it usually consisted of a brass tallow-cup screwed into the top of the steam chest or to the steam pipe and melted tallow was fed into the steam space at more or less regular intervals.

While steam pressures were low and piston speeds did not exceed 300 to 400 feet per minute this kind of lubrication answered very well, but as pressures and speeds increased the necessity for a more efficient lubricant than pure tallow became very apparent in the successful operation of steam engines.

An oil to be used as a cylinder lubricant, in order to give good results must possess certain essential properties.

It must be of high flash test, so that it will not volatilize or vaporize when in contact with the hot steam; it must have good viscosity or body when in contact with the hot surfaces, and should adhere to, and form a coating of oil so as to prevent wear and reduce as much as possible the friction of the moving parts.

In using pure tallow in connection with high pressure steam, it was often found after continued use that the acids which are present to a greater or less degree in all animal oils, had a very corrosive effect on the metal surfaces with which they came in contact; very often the cylinder walls and valves and valve seats would become pitted and corroded and the metal so softened by the action of these acids as to require expensive repairs.

The threads of the follower bolts and bolt holes would become eaten away to such an extent as to impair their holding power.

Some of the essentials to be desired in a cylinder lubricant are obtained to the greatest degree in the heavier or more dense and viscid of the petroleum oils, but there is one element in which a pure petroleum oil is usually lacking as a cylinder lubricant and that is its inability to adhere to a wet surface, and for that reason it is necessary that it be combined with some one or more of the various vegetable or animal oils.

There is always a certain amount of moisture present in the valve chambers and cylinders of a steam engine, due partly to condensation of the steam in the pipe on its way from the boilers to the engine and partly to the expansion which takes place in the cylinders.

A petroleum oil, while it may possess the proper viscosity and flash test, will not of itself mix with or form an emulsion with water and consequently will not stick to the moist surfaces, but will be easily washed out by the action of the steam; but animal and vegetable oils, while not so viscid as the petroleum oil, will combine with it and emulsify freely with water and when compounded in the proper proportions with a heavy petroleum produce a cylinder oil that is suitable for interior lubrication.

While the quality of a cylinder oil as shown by the use of testing instruments will give one a general idea of its lubricating value, the engineer who is studying the question of cylinder lubrication can determine more accurately its exact value by experimenting on his engines and pumps and under the conditions peculiar to his own plant.

Any engineer in charge of a steam plant knows that nearly every engine will indicate either audibly or otherwise perceptibly, any lack of lubrication.

A Corliss type of engine will usually indicate need of more cylinder oil by a slight groaning of the valves, if not loud enough to be heard, it can be detected by feeling of the valve stem, or by the vibration or trembling of the valve and eccentric rods.

Buckeye, Russell, Porter-Allen and other makes of engines with balanced valves will usually indicate a lack of oil by a rattling noise in the steam chest, rocker-arms and the eccentric and governor connections.

For instance, an engineer has submitted to him for trial three sample lots of cylinder oil, and he wishes to determine which is the most suitable and economical oil for him to use; he may notice after starting with the first sample that the valves work free and smooth on say, eight (8) drops a minute; he then reduces the oil feed gradually to four (4) drops, and then notices a slight tremor in the eccentric rods, and later, if a Corliss engine, he may detect a decided groaning sound in one or more of the valves.

If the oil feed is then increased to six (6) or seven (7) drops per minute and the valves begin to work freely again and when the oil feed is reduced to five (5) drops and the valves commence to work hard again, and the results are the same after repeated trials, the engineer can determine just how much of this particular brand of oil is required to keep the valves working smoothly and quietly.

The next thing in order is to remove the cylinder head or steam chest cover, or if a Corliss engine, draw out one of the valves and examine the wearing surfaces; if well lubricated they will present a dark glossy appearance, and a good coating of oil all over the interior surfaces.

The most reliable test of the condition of the surfaces is to wipe over them with a piece of soft white paper, such as a piece of ordinary newspaper; if a decided stain of oil is seen on the paper it is an indication of good lubrication. Another method is to wipe over the surface with several thicknesses of tissue paper and note the number of thicknesses that the oil has saturated through.

But if no stain of oil can be seen upon the paper and the surfaces have a dull appearance, and with traces of metallic wear it is a positive evidence that the oil is not lubricating properly.

Then, if another sample of oil is tried and it is found to require from ten (10) to twelve (12) drops per minute to keep the valves quiet, and the surfaces when examined showed little or no signs of oil, it would prove conclusively that it is a very poor lubricant, and would be a most expensive oil no matter how cheap in price per gallon.

But, if after trying the third sample it will be found that the oil feed can be reduced to one (1), two (2), or three (3) drops per minute, or, perhaps one (1) drop every two minutes, and kept at that rate for hours, without showing any evidence of lack of perfect lubrication, and the surfaces after standing cold for several hours still show a good coating of oil and no rust or "raw spots," and these results hold good on all the engines and pumps in the plant, it would prove conclusively that this oil will be the cheapest to use no matter what the price per gallon may be and regardless of all laboratory tests.

CYLINDER OIL LUBRICATORS.

The successful lubrication of a steam cylinder will depend greatly upon the appliances by means of which the lubricant is fed to the wearing surfaces.

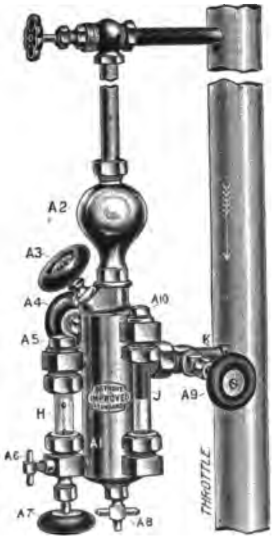

Fig. 13. Exterior View Detroit Lubricator.

For steam cylinder lubrication the hydrostatic or sight feed type of lubricator is in most general use, this type of lubricator depends for its operation upon the displacement of the oil by a body of water which is formed by the condensing of the steam in the condensing chamber of the lubricator, the water in passing into the oil chamber displaces the oil, forcing it up through the sight-feed glass, whence it flows through the discharge pipe to the engine.

There coming in contact with the hot steam it is atomized and conveyed in the form of spray to the wearing surfaces of the valves and cylinders.

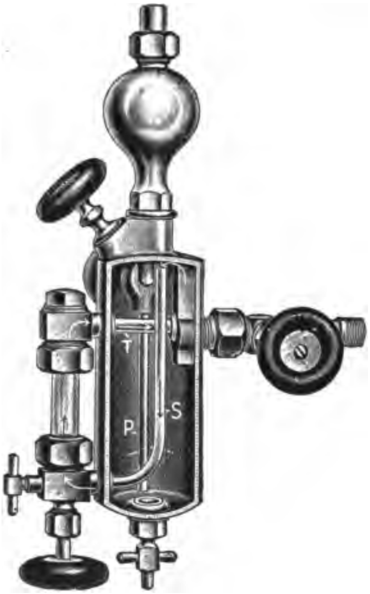

Fig. 14. Interior View Detroit Lubricator.

Figure 13 shows a well known type of lubricator manufactured by the Detroit Lubricator Co., Fig. 14 shows its internal construction.

The steam entering the condensing pipe and condensing bulb (A2) flows in the form of water through the tube (P), when the valve (A4) is opened, to the bottom of the oil chamber, steam also enters through the connection (K) and tubes (T) and fills the glass with condensed water.

The lubricator being filled with oil through the filling hole (A3) and the valve (A4) being opened, the water flows through the pipe (P) to the bottom of the oil chamber and forces the

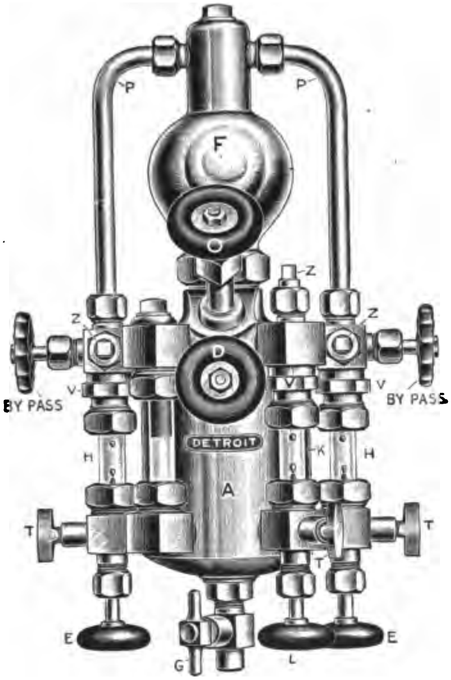

Fig. 15. Triple-Feed Locomotive Lubricator.

oil down through the tube (S), and when the valve (A7) is opened it goes up into the sight feed glass (H) in the form of drops and from thence flows through the pipe (T) and (K), where it enters the main steam pipe and is carried by the current of the steam to the wearing surfaces.

The gage glass (J) indicates the amount of oil in the lubricator, the valve (A9) shuts off the pressure from the oil discharge pipe (T) and should not be closed except when it is necessary to clean or replace the glass (H), Plugs (A5) and (A10) allow access for cleaning or replacing the glasses.

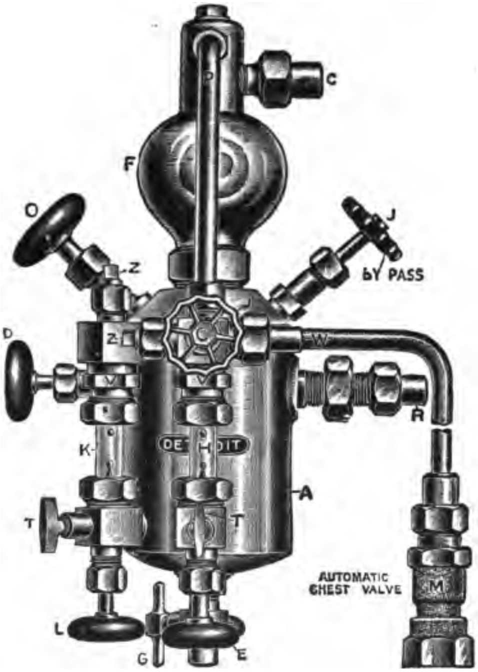

Fig. 16. Side View Triple-Feed Locomotive Lubricator.

(A8) is the drain through which the condensed water is drawn off (A6) drains the glass (H) and the oil feed is regulated by the valve (A7).

In the case of locomotives it is desirable that the main cylinders and the air pump be supplied by one lubricator.

For this purpose the Detroit Lubricator Co. make a very efficient appliance which is known as their "No. 3 C, Triple Feed Locomotive Lubricator," with "Automatic Steam Chest Valves and By-pass Valves for Auxiliary Oiling."

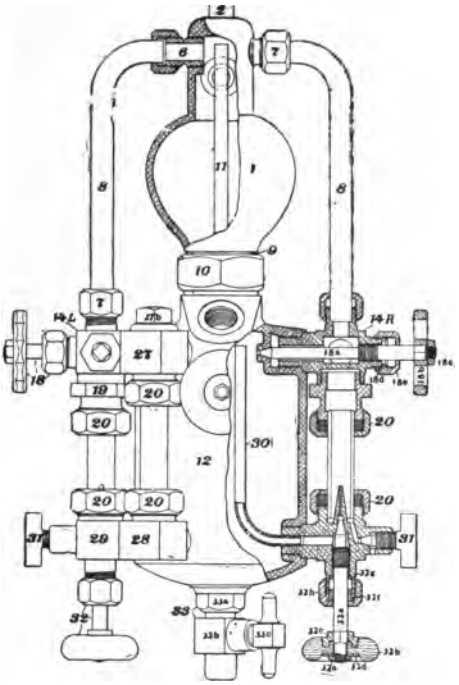

FIG-1-FRONT ELEVATION

Fig. 17. Sectional View Triple-Feed Lubricator.

Figures 15 and 16 show external front and side views, and Fig. 17 shows sectional front elevation, while Fig. 18 shows a cross sectional view, as if the lubricator were cut open horizontally on a level with the upper sight feed arms.

Figure (19) shows an internal view of the sight feed glass with the Automatic Safety Valve above the glass.

Figure (20) shows the manner of inserting a new glass.

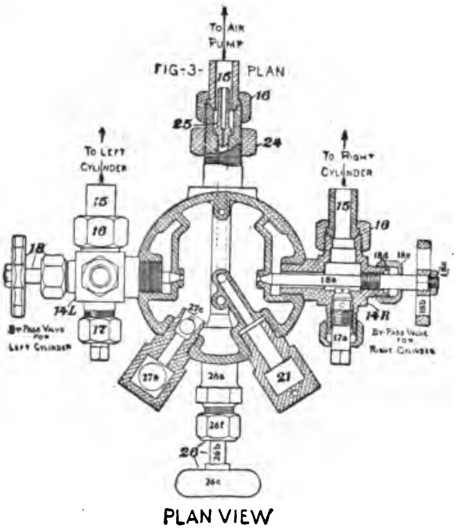

Fig. 18. Sectional View Triple-Feed Lubricator.

F—Condenser.
A—Oil Reservoir.
O—Filler Plug.
G—Drain Plug.
D—Water Feed Valve.
EE—Feed Regulating Valves to Right and Left Hand Cylinders.
L—Feed Regulating Valve to Air Pump.
ZZZ—Automatic Shut-off Valves.
JJJ—By-pass Valves to Right and Left Hand Cylinders and to Air Pump.
WW—Coupling to Right and Left Hand Cylinders.
R—Coupling to Air Pump.

DIRECTIONS FOR APPLICATION TO LOCOMOTIVE.

1st. Secure the Lubricator to boiler-head or to top of boiler by strong bracket.

2nd. Connect Lubricator at coupling C to boiler space, using copper pipe of 13-16 outside diameter or its equivalent, and a ¾-inch valve at boilers.

3d. Connect with tallow pipes at couplings WW, and with air pump at coupling R.

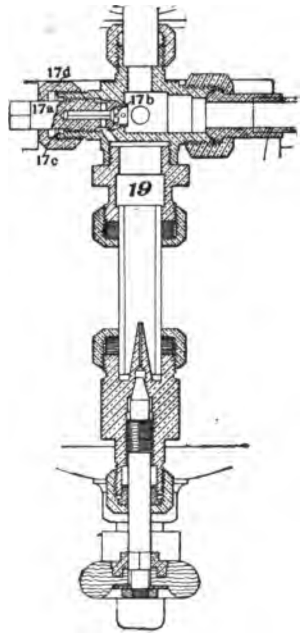

Fig. 19. Showing Sight Feed and Automatic Shut-Off Valve.

4th. Automatic chest plugs furnished with the Lubricator can be threaded to fit plugs already on steam chests.

5th. The fitting to which the steam chest valve is attached should be bored to ¼ inch hole.

Figure (6) shows an internal view of the sight feed glass with the automatic safety valve above the glass.

Figure (7) shows the manner of inserting a new glass.

LUBRICATING APPLIANCES.

Directions for operating the No. 3 C. Triple Feed Lubricator: When the lubricator has been connected allow the steam to blow through it thoroughly so as to remove all dirt, lint and other foreign matter, then close all the valves.

First, warm the oil so that it will flow freely, remove the filler plug (O) (Fig. 5) and fill the reservoir full with clean strained oil.

Second, to start the lubricator open the boiler valve gradually until wide open, and allow sufficient time for the condenser and feed glasses to fill with water, keep this valve open while the lubricator is in operation.

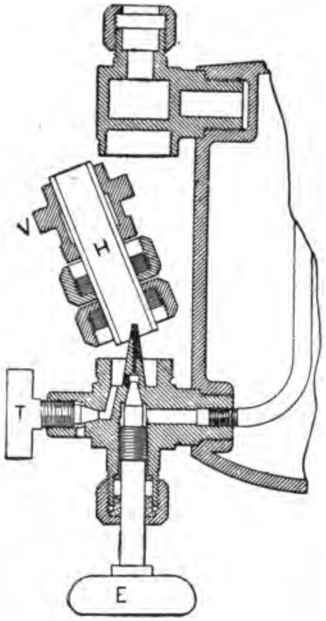

Fig. 20. Showing Manner of Replacing Sight Feed Glass.

Third, open the feed water valve (D).

Fourth, regulate the flow of oil to the right and left hand cylinders by the valves (EE), and to the air pump by the valve (L).

When re-filling the lubricator always close the valves (EE) and (L) in advance of the valve (D). Open the drain valves (G), then the filler plug (O) and allow the water to flow out, refill with oil, proceed to operate as before.

The valves (ZZZ) contain automatic shut-off valves which will shut off the steam and water in case the glasses should break.

The by-pass valves (JJJ) should be opened only in case one or more of the glasses become broken; in case one of the glasses should break close the feed regulating valve under the broken glass and open the by-pass valve, adjust the oil feed the same as with the regulating valve, being careful not to give too great an opening of the by-pass valve.

This feature of the lubricator does away with the necessity of a "hand oil pump," and in no case is it necessary to close the locomotive throttle or any valve of the lubricator except the valve under the broken glass to use the by-pass as an auxiliary oiler.

To insert a sight feed glass slip the gland nuts and the extension sleeve (V) ovr the glass as shown in figure (7), then pass the lower end of the glass over the point of the nozzle and place the glass in position, then screw the valve (V) in place and tighten up the gland nuts.

Do not use water gage glass in replacing broken lubricator glasses, as regular lubricator glasses are more suitable, and can be obtained very cheaply and cut to the exact length, and will be more satisfactory.

POWELL LUBRICATORS.

One of the best and most extensively used lubricators is the "Class A" up-feed lubricator, by the Wm. Powell Co.; it is made in sizes from one-third of a pint to one gallon, and made to stand heavy pressures.

Figure 21 shows an external view of the "Class A" lubricator, and the letters designating its different parts.

This lubricator is for use on single cylinder engines, but for locomotives, compound and triple expansion stationary and marine engines this firm makes a double or triple feed lubricator which is preferable to the single feed, as two or three sight feeds are combined with one oil chamber.

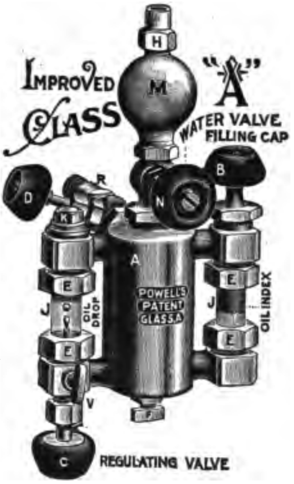

Fig. 21. Powell Lubricator.

A—Oil Reservoir.
B—Filling Cup.
C—Valve to Regulate Oil Drops.
D—Shut-off Valve.
E—Packing Nuts.
F—Drain Valve.
H—Coupling for Condensing Pipe.
JJ—Sight Feed and Index Glasses.
K—Plug for Removing and Inserting Glasses.
M—Condensing Chamber.
N—Valve to Regulate Water from the Condenser.
V—Valve to Drain Sight Feed Glass.
R—Attaching Shank and Valve.

Figures 22 and 23 show external and internal views of the Powell Duplex Condenser and Double up-feed Locomotive Lubricator.

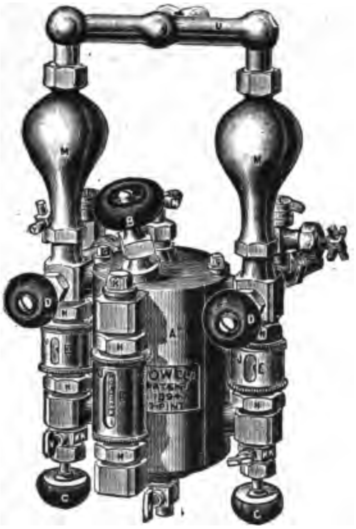

Fig. 22. External View Double Up-Feed Locomotive Lubricator.

DESCRIPTION OF EXTERNAL VIEWS.

A—Oil Chamber.
B—Filing Cap.
CC—Oil Drcp Regulating Valves.
DD—Ejector Valves.
EE—Protecting Shields.
GG—Oil Tube Cleaning Plugs.
F—Drain Valve for Oil Chamber.
HH—Packing Nuts.
JJJ—Sight Feed and Index Glasses.
KKK—Removable Bonnets for Replacing Glasses.
LL—Auxiliary Oil Cups.
II—Adjustable Shield Collars.
MM—Condensing Chambers.
N—Water Valve.
O—Bracket Stud and Lock Nut.
RR—Condensing Couplings to Cylinders.
T—Connecting Coupling to Boiler.
VV—Valves for Cleaning out Sight-Feed Glasses.
YY—Valves for Auxiliary Oil Cup.

The operation of this type of lubricator can be readily understood by a study of the sectional views.

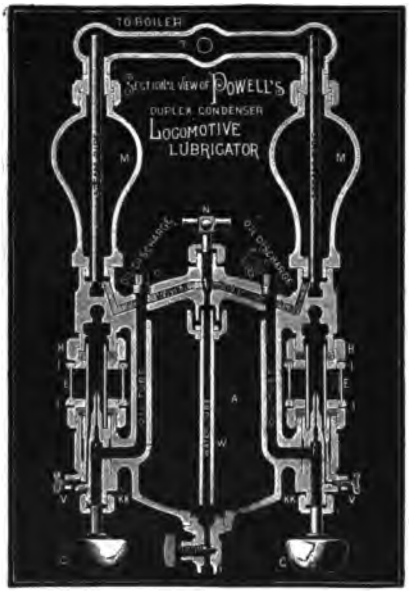

Fig. 23.

DESCRIPTION OF INTERNAL PARTS.

A—Oil Chamber.
CC—Oil Drop Regulating Valves.
EE—Brass Protecting Shields.
F—Drain Valve.
GG—Removable Plugs to Clean Oil Tubes.
HH—Packing Nuts.
II—Adjustable Rings.
JJ—Sight Glasses.
KK—Removable Cages to Replace Glasses.
MM—Condensers.
N—Water Valve.
T—Connecting Coupling to Boiler.
VV—Cleaning Valves for Sight Glasses.
W—Water Tube.
X—Water and Oil Trap.

One of the features peculiar to this lubricator is the provision made to prevent "cross feeding" and "syphoning" of oil, which is liable to occur on locomotives when going down grade with the steam shut off from the cylinder. "Cross-feeding" is provided against by having a separate and independent condensing chamber and steam pipe to each oil delivery pipe; the connection between the two cylinders is entirely cut off and each sight feed acts independently of the other.

"Syphoning" is prevented by means of the oil and water trap which is connected to the top of the water tube (W) and insures an adequate and positive supply of water to the lubricator after it is filled with oil.

After adjusting the feed valves (C C) to the desired number of drops per minute they need not thereafter be disturbed, as the closing or open-

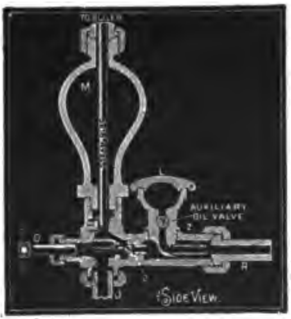

Fig. 24.

DESCRIPTION OF AUXILIARY OIL FEED VALVE.

D—Ejector Valve.
J—Sight Glass.
L—Auxiliary Oil Cup.
M—Condenser.
R—Discharge Coupling to Cylinders.
Y—Auxiliary Oil Valve.
Z—Auxiliary Oil Ejector Tube.

ing of the ejector valves (D D) or the water valve (N) will at once stop or start the lubricator to feeding; this is a convenience that all engineers will appreciate.

Another valuable feature of this make of lubricator is the auxiliary cups (L). By means of these an extra supply of oil can be fed to the cylinders without disturbing the feed valves (C C). By pouring oil into the auxiliary cups and opening the valves (Y Y) the oil can be instantly blown by live steam to the steam chests and cylinders. When the auxiliary feed is not in use valves (Y Y) should be kept closed.

These lubricators are very simple in their operation. To refill and start close the valves (D D) or (N) and draw off the water through the drain (F), then close (F) and fill the oil chamber through the filling plug (B), close (B) and open valves (D D) or (N) and the oil will commence feeding through the sight feeds according to the rate at which it has been set.

Another valuable feature in connection with the Powell type of lubricator is the "Filler" shown in Fig. 25, which can be attached to the lubricator by means of the shank which is screwed into the filling opening above the index glass, this filler saves time in filling the lubricator and the consequent annoyance and loss of oil by "running over" when filling a heavy oil through the opening.

TO OPERATE THE FILLER.

When filling the lubricator for the first time, first fill it with water, then attach the filler by means of the shank and lock-nut (6 and 7), close the shut-off valve (5), remove the lid (1), and fill the oil chamber (2) with oil, move the lever of the shut-off valve to position (4), then open the drain valve at the bottom of the lubricator and allow the water to run out; as fast as the water runs out the oil will run in. As soon as the oil begins to show, close the drain valve and shut-off valve, and the lubricator is ready for operation; but be sure that the shut-off valve is closed before opening valves (D) and (N) on the lubricator.

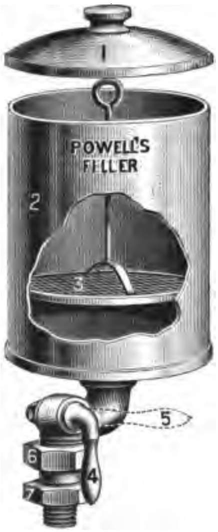

Fig. 25. Lubricator Filler.

Always keep the filler full of oil, and it is a good plan to have a filler that is of a greater capacity than the lubricator.

FORCE-FEED LUBRICATORS.

Another type of cylinder lubricator which has many advocates among engineers is the force feed or mechanically operated lubricator.

Figure 26 shows a cut of a well known lubricator of this kind called the Rochester automatic, as will be seen, this lubricator consists of an oil chamber to which are attached one or more pumps which are actuated from the valve stem or other reciprocating part of the engine.

These lubricators are especially valuable on tug boats and steamers, mine hoisting and haulage plants, etc., where the work is intermittent, as the lubricator starts the feed when the engine starts and stops, feeding when the engine is stopped.

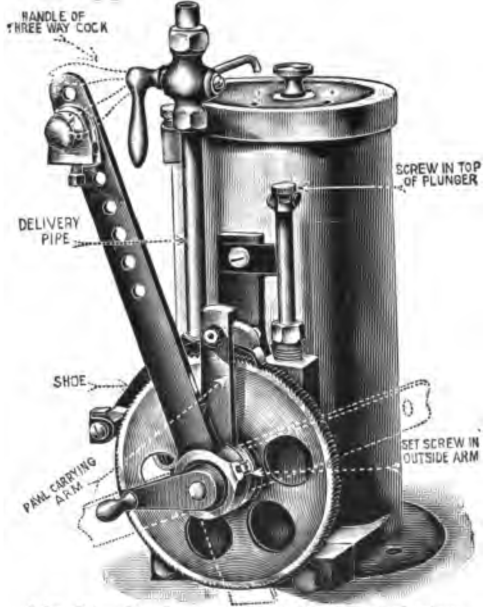

Fig. 26. Rochester Force Feed Lubricator.

CARE OF SIGHT FEED LUBRICATORS.

It is very important in the operation of sight feed lubricators that they be properly attached. Many engines are using more oil than is necessary, for the reason that the lubricator is improperly attached.

In connecting up a lubricator its oil discharge shank should be attached to a nipple having a running thread, which should be screwed into the steam pipe so that the end will project clear through into the center of the steam pipe.

If the shank is simply screwed into the pipe or the throttle casting it will probably not project clear through and a very large percentage of the cylinder oil will spread out over the interior surfaces of the steam pipe, throttle valve and steam passages; a substantial proof of this can be noticed on many engines by the tendency of the oil to ooze out through the joints and packing.

In order that the best results can be obtained with the least amount of oil it is very essential that it should mingle with the steam and be carried direct to the wearing surfaces and not deflected to where it is not needed.

After attaching a lubricator and before putting it in operation it is very important that every union, valve-stem and screwed joint be perfectly tight, a slight leakage will very materially affect the proper working of the lubricator.

A condensation pipe of sufficient length should be attached above the lubricator to insure weight of water to displace the oil and force it up into the sight-feed glass; in ordinary practice it is generally found that from 12 to 18 inches of condensing pipe is sufficient to insure good results.

The lubricator should always be warm or nearly hot, in order that a dense viscous oil will be thin enough to flow freely through the sight-feed glass.

There are several reasons why a lubricator may fail to operate properly; leaky joints will cause the lubricator to feed irregularly and sluggishly, the drop of oil rises in the sight-feed glass by virtue of the difference in gravity between it and the water, the steam pressure in the condensing pipe forces the oil up through the sight-feed, and if the pressure is reduced by leaks it will not force the oil as it should.

A very common cause of trouble is the clogging of the sight-feed glasses; this may be due to fibres of waste or other foreign matter getting into the feed valves, or into the discharge passages at the top of the glasses.

The packing at the top of the sight-feed glass may have been squeezed out over the top of the glass, or the oil tube leading to the sight-feed glass may have choked up.

A lubricator like any other piece of mechanism, requires care and attention. Care should be taken to see that no foreign matter enters it, and it will be found to be a good plan to occasionally feed a lubricator full of carbon or kerosene oil, or allow it to stand full of kerosene for several hours, and then empty it and allow steam to be blown through.

One cause for complaint of the oil sticking to the inside of the glass is often due to the sight-feed glass having been broken and replaced by a piece of water-gage glass. This glass, while of the same outside diameter, is thicker than a regular lubricator glass, and consequently the inside diameter is smaller and the drops of oil will often cling to the inside surface. It is a good plan to have a few regular lubricator glasses on hand to replace broken ones. Glasses of the proper length and diameter with fused ends can be obtained from the manufacturers of the lubricators, or from local dealers.

Another cause for clogging of the sight-feed glass is, that when the lubricator is allowed to run empty the last few drops of oil often form in bubbles which in breaking will cause the particles of oil to stick to the inside of the glass.

The top of the feed valve outlet may have been dented out of its proper shape and the drop in rising through the cone will fall to one side and trail up the glass. The remedy for this is to file or grind the cone into shape or to solder a piece of fine wire to the side of the cone, letting the end project half an inch or so above the top of the cone. The oil will follow up the wire and pass up without touching the glass.

Another difficulty sometimes encountered is what is known as "churning." This is caused by not filling the lubricator completely full of oil, and if there is not enough condensed water to supply the deficiency the steam will follow and mixing with the oil churn it into a foam. When this occurs the lubricator should be emptied and cooled off and refilled with oil, and time allowed for condensation to form in the condensing chamber before starting.

Whenever a sight-feed glass becomes foul and coated it is of very little use to attempt to clean it by blowing steam through it.

Remove the plug at the top of the sight-feed glass (all modern lubricators are equipped thus), and with a little carbon oil or turpentine on a swab sponge out the inside of the glass, being careful to see that no lint or fibres of waste remain in it. Fill the glass with warm water and replace the plug. In doing this always use a wooden stick; never use a steel or other metal wire or rod, as the slightest touch on the inside of the glass with metal is apt to cause the glass to break.

If the glass is cleaned occasionally and care is taken in filling and starting the lubricator there need be no cause for complaint of foul glasses, no matter how dense and viscid the oil may be.

The drops of oil feeding through a sight-feed lubricator will vary in size with the gravity, viscosity, the size of the aperture through which the oil flows and the temperature of the oil.

In order to ascertain the amount of relative difference in the size of drops of different brands of cylinder oil and the length of time it would take for a given quantity of oil to feed out, Mr. T. J. Donahoe, chief engineer, and Mr. John Conners, assistant engineer of the "Times" Building, Pittsburg, made several tests from which the following table was compiled.

The lubricator used was a modern type of "Detroit," quart size, with each oil tried the lubricator was filled completely full, the time of starting noted, the rate of feed and the temperature kept constant and the number of hours and minutes noted that it took to run empty.

TABLE X.

Model Cylinder Oil, 3462 drops to the Quart.

	hrs.	min.
At 1 drop per minute, ran empty in............	57	45
At 2 drops per minute, ran empty in...........	28	52
At 4 drops per minute, ran empty in...........	15	26
At 8 drops per minute, ran empty in...........	7	13

Capitol Cylinder Oil, 6080 drops to the Quart.

	hrs.	min.
At 1 drop per minute, ran empty in...........	101	20
At 2 drops per minute, ran empty in..........	50	40
At 4 drops per minute, ran empty in..........	25	20
At 8 drops per minute, ran empty in..........	12	40

600 W. Cylinder Oil, 4480 drops to the Quart.

	hrs.	min.
At 1 drop per minute, ran empty in...........	74	40
At 2 drops per minute, ran empty in..........	37	20
At 4 drops per minute, ran empty in...........	18	40
At 8 drops per minute, ran empty in..........	9	20

20th Century Cylinder Oil, 3120 drops to the Quart.

	hrs.	min.
At 1 drop per minute, ran empty in...........	52	00
At 2 drops per minute, ran empty in...........	26	00
At 4 drops per minute, ran empty in...........	13	00
At 8 drops per minute, ran empty in...........	66	30

CUTTING AND SCORING OF CYLINDER SURFACES, VALVES AND VALVE SEATS.

One of the most annoying things that can happen to an engineer is to find that the interior surfaces of the engines in his charge have been cut and scored, and very often the cause of it is attributed to the lack of proper lubricating quality of the cylinder oil used.

While in some instances and under certain conditions, such as a very heavy piston dragging over improperly lubricated surfaces, or valve and valve seats being made of unsuitable metals the grade of oil may have had something to do with the cause of the cutting, or in other words, if the oil had been of a more suitable quality the cutting might not have occurred; but in a majority of cases a close investigation would have proven that the trouble was not due to lack of quality of the oil used.

It has been noticed by the author that many cases of cutting have occurred shortly after first starting up new engines, and when one considers the manner in which a great many engines are erected, one wonders that these cases are not more frequent.

The mould and core sand may not have been thoroughly cleaned out of the cylinder castings; the castings often contain small blow holes in which the sand and lathe and planer cuttings find lodgement, the inner surface of the steam pipe is often coated with a thin layer of hard scale which under the continual contraction and expansion will loosen from the inner surface of the pipes; oil is used in cutting the threads on the ends of the pipe, and grit, sand and dirt will accumulate and stick to the oily inner surfaces; large size pipes are always cut to lengths with a square nose cutting-off tool, this tool nearly always leaves thin burrs or chips of iron sticking to the inner edge of the pipe, and these are apt to break off after the pipe is erected in place.

This accumulation of sand chips and dirt, if not thoroughly cleaned out before the piping is erected, will be carried by the rapid flow of steam toward the engine, and if there is no separator on the steam line some of this foreign matter will in time pass through the throttle valve and catch between the engine valves and their seats or in the piston rings and cause a severe case of cutting and scoring.

Before the piping is erected each length should be hammered so as to loosen the scale from the inner surfaces, the burrs and chips broken off, and the grit and dirt cleaned out; then after the piping has been connected to the boilers and before it has been bolted onto the engine a full head of steam should be turned on and all remaining dirt blown out.

As an instance of the importance of this reference may be made to the case of a large engine in a steel works which was erected very hastily in order to get the machinery into operation as soon as possible. The cylinder was so badly cut that it was necessary to re-bore it in less than a month after first starting up, and the cavity above the throttle valve seat was found to be filled with dirt and chips. A large engine in a power house in Pittsburg was erected and a separator attached to the steam pipe close to the engine, and in less than a week after first starting up it was found that the steam trap on the drain pipe of the separator failed to operate; and on examining it, it was found to be completely choked up with sand, dirt and pipe scale. If the engine had not been provided with a separator some of this dirt would have undoubtedly been carried into the engine and the surfaces would have been ruined. This is a "talking point" that the makers of separators never seem to have used in their catalogues in speaking of the merits of their goods.

One of the greatest and most frequent causes of the cutting of cylinder surfaces can be attributed to setting out too tightly of the the piston rings, especially where the old-fashioned "jack-screw" packing is used. An engineer in his efforts to center his piston and get his rings steam tight, is very apt to set them out too tight, thus making unnecessary friction and preventing the oil from getting on the surface of the rings. One should always bear in mind that it is not so much the oil that is on the cylinder surface that makes good lubrication as it is the quantity of oil that gets between the rings and the cylinder walls.

The rings should never be allowed to wear to a sharp edge, but should be slightly rounded off with a file. If worn to a sharp edge the ring acts as a scraper and scrapes the oil ahead of it, preventing it from getting under them, besides increasing the tendency to cutting when too tight, while if slightly rounded off it will allow the oil to get under the rings more easily.

Experience has proved that the importance of keeping the piston rings very tight has been greatly over-estimated. Most modern engine builders equip their pistons with light steel springs to hold the rings out against the cylinder walls, while the piston rings of other makes of engines are often simply split cast-iron rings sprung into grooves in a solid piston, keeping it steam tight by their own elasticity, no bolts or springs being used.

Many of the builders of large engines are equiping them with a "tail rod," or a continuation of the piston rod through the back head. This tail rod is usually of hollow forged steel about 10 or 12 inches in diameter; at its extreme end is fastened a "shoe" or slide similar to a cross-head slide. This shoe slides back and forth on a pedestal, the piston being supported in the middle of its length and the rod being so large in diameter that the weight of the piston is kept up off the bottom of the cylinder and only the surface of one narrow ring is necessary to keep the steam from blowing through, while there is not the slightest liability of cutting.

Cylinder cutting in one case was caused by the substitution of steel piston rings for cast-iron rings. The engine was a large compound Corless and the high pressure cylinder had originally been equipped with iron spring rings; owing to frequent breakages cast-steel rings were put in and in a short time it was found that the top side of the cylinder was badly scored; the hard steel rings had worn to a sharp edge, and fitting tightly had cut into the soft iron of the cylinder. If the rings had been chamfered or rounded off at the edges this might not have occurred.

It is a fact that some engine builders, instead of using a good close-grained re-melted cast-iron for their cylinder castings, will make them of a soft open-grained metal, thus increasing the liability to excessive wear and cutting. As to the bad effects of using a fibrous instead of a granular metal it might be well to mention an instance in which a large engine, the valve and valve-seats of which had become so badly worn out of true as to require a new valve; as a temporary expedient the seat was chipped and filed as smooth as possible, a false seat of steel boiler plate was fastened on with countersunk screws. But soon after starting up it was noticed that something was wrong with the valve. The best quality of oil obtainable was supplied freely without any relief. After a few days running the steam chest cover was removed. The whole

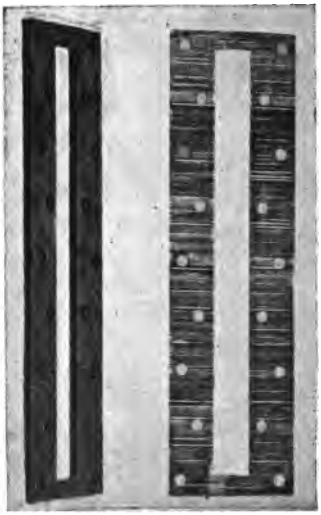

Fig. 27. Scored Valve Seat.

surface of the valve and its seat was found to have been worn into a series of grooves and ridges from one-eighth to one-quarter of an inch in depth, and the whole plate which was originally three-eighths of an inch was worn down to one-eighth of an inch in thickness.

Figure 27 is from a photograph of one of the plates after it was removed from the engine.

GROANING OF PUMP AND ENGINE VALVES.

The groaning noise often heard in connection with the operation of steam machinery, and especially the duplex pumps used on elevator service, is very annoying, especially in offices, hotels and other public buildings.

The cause of this noise is usually attributed to the quality of the cylinder oil used to lubricate the valves. The duty to which hydraulic elevator pumps are subjected is more or less intermittent; when the elevator is not in use, the pump stands still and when the elevator starts the pump starts.

All elevator pumps are equipped with a pressure regulator or governor on the steam pipe by means of which the speed of the pump is controlled by the pressure of the water. When the pump is not running the steam valve of the regulator remains closed till the elevator is started. During the time that the regulator valve is closed the steam in the steam pipe is condensing, and the water is accumulating above the valve, which when opened permits it to rush through with the steam, and has a tendency to wash off the oil from the wearing surfaces, allowing them to come in direct metallic contact with each other, and the action of the valve on the seat causes the grinding and groaning noise.

It is often found that one grade or brand of oil will give better results and keep the valves quieter under these conditions than another. The reason is that one oil may have a greater affinity to a wet metallic surface and cling to it better than another grade; but the cause of the trouble will usually be found to be due to the water of condensation.

In piping up steam pumps for elevator service provision should always be made by means of a separator or a drain pipe to prevent the water entering the steam chests, as water is the worst enemy to perfect lubrication.

This will apply to engines as well as to pumps, as the cylinder oil will be more efficient in connection with dry steam than with wet steam. But instances have occurred in which the steam was comparatively dry and yet the valves groaned badly; no matter what the quality of oil was, or the quantity used, the valves would not run quietly; an investigation showed that they had worn to such a perfect fit on their seats and the surfaces were in such close contact that neither oil nor steam could get between the surfaces.

In one instance in particular that came to the author's notice the exhaust valves of a large Corliss engine groaned so badly as to be heard all over the engine room, and they would not run quietly no matter how much oil was used. On examining the valves a bright spot about three inches in diameter was found on the under side of each valve at the back end. These spots were as bright as glass and when rubbed with a piece of paper did not show a trace of oil, while the rest of the valve surface was covered with oil. Corresponding bright spots were found on the valve seats. The bright spots on the valves were due to hard places in the iron; these hard spots standing above the general surface wore themselves into the metal of the cylinder casting.

A few strokes with a smooth file over these bright surfaces remedied the trouble, and after that there was no more groaning.

DEPOSITS OF STICKY AND SOLID SUBSTANCES IN STEAM CYLINDERS.

In certain conditions an engineer will sometimes find in the interior of his cylinders an accumulation of a sticky, pasty substance which in some cases has completely filled up the cavities and spaces in the pistons and steam chests, and he may think that this mass of dirt is caused by the use of an inferior grade of cylinder oil. Now, while a very poor and improperly compounded cylinder oil used in large quantities may sometimes cause an accumulation of this kind an investigation usually shows that this dirty mass is composed principally of "boiler mud," and a chemical analysis would have proved that it contains silica, magnesia, lime and other solids usually found in boiler water, also some oxide of iron or iron rust, together with enough oil to form the whole into a pasty mass.

An ordinary good grade of cylinder oil does not contain any substance that of itself can form any such deposit. It has been stated by some engineers that the oil becomes decomposed by the heat of the steam and forms this deposit. This cannot be possible, for the reason that the highest temperature attainable in the cylinder is that due to the steam, which at 100 pounds' pressure would be 338 degrees Fhr., while a cylinder oil will have a fire test of over 500 degrees, and it would require a continuous exposure to a dry heat of about that temperature to cause the oil to change its condition.

A 100-horse-power boiler evaporating 30 pounds of water per horse-power per hour, which contains 15 grains of solids and suspended matter per gallon, will, in a day of 24 hours, have a deposit of 10 pounds of solids, a large per cent. of this earthy matter which is held in suspension in the water, will for a time float on the surface of the water in the boiler, and if the boilers are fired hard or are liable to foaming or priming, some of this substance will be carried over with the steam into the engine, and coming in contact with the oily surfaces will adhere to them and form this accumulation.

Evidence of this may often be seen at the leaky joints of the main steam pipe and around the stop valve and throttle valve stems, and this is another emphatic argument in favor of a separator in the steam pipe to trap off all condensation and solids that would otherwise be carried over into the engine. The iron rust often found in these deposits usually comes from the inside of the pipes.

A number of samples of deposits collected from stationary engine and locomotive cylinders running under all kinds of conditions, and also from marine engines, showed when analyzed an average composition as follows:

Oil, animal, vegetable and mineral	20 to 60 per cent.
Lime, magnesia, silica and other earthy substances,	10 to 80 per cent.
Iron, oxide or iron, lead, zinc and other metals,	From a trace to 10 or 20 per cent.

The oil, of course, came from the lubricant used, and the iron and oxide of iron, or iron rust, may be accounted for by the wear of the cylinders and pistons, the scale and rust came from the inside of the pipes; but the lime, silica and other earthy substances must have been carried over with the steam from the boilers.

CYLINDER DEPOSITS.

Mr. Charles H. Garlick of Pittsburg, Pa., one of the best posted authorities on lubrication in the country, mentions an instance of this kind that came to his notice where an analysis showed as follows:

Petroleum oil with a small amount of saponifable oil	30.80 per cent.
Oxide of iron	20.00 per cent.
Silica, magnesia and other earthy matter	38.94 per cent.
Carbon	10.26 per cent.

A very peculiar case occurred a few years ago at a large steel works in Western Pennsylvania. In this mill there were eight large engines in use in the various departments. Two were of the Corliss type, some were plain slide valve engines, and others were old Ohio river steamboat engines with poppet valves and long wooden connecting rods or "pitmans," and all of them using the same brand of cylinder oil, a very good grade, which had been in use for a year or more.

It was the custom in this mill, and the same custom prevails in many rolling mills, to take off the cylinder head and examine the packing rings frequently. One Saturday afternoon the engineer in charge of one of the old steamboat engines found on opening the cylinder that the spider of the piston was full of a soft black substance. As he had never seen anything of this kind in the piston before he naturally thought that the oil had been changed, but it was found that the oil was of the same brand as had been previously used, and there was no trace of any of this substance in any of the other engines in the works, all using the same oil and taking steam from the same battery of boilers.

The deposit was analyzed and found to contain about 65 per cent. oil and about 35 per cent. lime, magnesia and silica combined. The piston was cleaned and the next Saturday it was as bad as on the previous Saturday, and this continued for several weeks. As there was no trace of any of this substance in any of the other engines it was accounted somewhat of a mystery until one of the engineers happened to notice that the trap and drain pipe of the separator was clogged up. It was cleaned out and the next Saturday on taking off the cylinder head they found no deposit, and there was no trouble of this kind afterwards.

It was evident that the separator drain pipe having become choked up, the separator filled up with the water that was carried over from the boilers and the entrained sediment rising to the surface was swept by the velocity of the steam into the cylinder, and accumulating with the cylinder oil, which was very dense and viscous, formed this deposit. As is usually the case in rolling mills there was no allowance of oil made to the engineers and they were free to use as much as they wanted. In this instance they were using more oil than there was any necessity for and the surplus oil tended to aggravate the trouble. Had no more oil been used than was needed to lubricate the cylinder surface most of this solid matter would have gone out with the exhaust steam.

In another instance that came to the author's notice the cylinder surface of an engine had been badly scored by the sharp edges of the piston rings, and on taking out the rings it was noticed that they were coated and the grooves filled with a thick accumulation of a black gummy substance. The engineers thought at first that the oil was deficient in quality, but on test it was found to be up to the standard in viscosity, flash and fire test.

It was noticed on examining a lump of the deposit that it was quite heavy, and on testing it with a common horseshoe magnet it was proved that it contained a large per cent. of iron. Some of the deposit was then washed in gasoline and the sediment when dried all adhered to the magnet. The sharp edges of the rings, which had been set out too tight, had dug into the softer iron of the cylinders, and the oil combining with the iron cuttings, caused this formation.

Another case of deposit in the engine and which emphasizes the importance of having a separator in the steam pipe, occurred at a large fire-brick works near Pittsburg. The valve of a large slide valve engine broke in two, and on opening the steam chest the surfaces of the valve and its seat were found to be coated with a layer of a dark red substance, dried on so tightly as to require considerable labor to remove it. As usual it was at first supposed that the oil was defective in quality, and a complaint was made against it. The author was sent for to investigate it, and it was found that not only was there a large amount of this deposit in the steam chest and cylinder, but that the throttle valve was found to be so full of this substance that it could hardly be moved.

Inquiry revealed the fact that a short time before the accident the firemen had mixed a large dose of boiler compound and pumped it into the boilers. This caused the boilers to foam badly and the water in going over with the steam carried a large quantity of the sediment and scum that was floating on the surface with it. When it reached the steam chests and came in contact with the wearing surfaces it stuck to them and the friction became so excessive as to cause the valve to break. The sediment owed its dark red color to the fact that the water came from the Monongahela river, which at that time of the year, during low water, was heavily charged with sulphuric acid from the coal mines.

To prove that this trouble was not the fault of the oil the steam chests and cylinders of some of the other engines in the works which took steam from another battery of boilers were opened and found to be in excellent condition, and well lubricated.

EFFECTS OF SOME BOILER COMPOUNDS ON CYLINDER LUBRICATION.

In certain conditions the use in boilers of boiler compounds containing potash, soda or other substances of like nature, have a deleterious effect on the lubrication of the wearing surfaces of steam cylinders.

If the water in the boilers become very heavily charged with compounds of this nature, it will increase the tendency to foam and prime, and the water carrying over into the engine with the steam, saponifies the oil and washes it off, leaving the surfaces dry and greatly increases the friction of the piston and valves.

In a particular instance that came to the author's notice, a battery of water-tube boilers had become very badly scaled up and a boiler compound was fed very freely to loosen and dissolve the scale. This being in a steel works, the blooming mill engines, which were subjected to very heavy duty, began to work very badly; the valves worked hard and stiff, no matter how much oil was fed to them; and the cylinders when opened were dry and after standing an hour or so would become badly rusted. As the cylinder oil was of a very good grade and freely used and had hitherto given satisfaction, the chief engineer was greatly puzzled until he noticed that the water dripping from the cylinder drain cocks was heavily saturated with alkali.

On discontinuing the use of the compound for a few days it was found that the valves began to work freely and an inspection of the cylinders showed them to be well lubricated and in as good condition as ever.

To determine if the water contains alkali, draw some of the condensed water from the cylinder cocks or other convenient place, and dip a piece of red litmus paper (which can be obtained at any dealer in chemicals) into the water; if the water contains any substance of an alkali nature the paper will turn blue in color.

If there is no alkali in the water the paper will not change its color.

To test for acid use blue litmus paper; if any acid be present in the water the paper will turn red.

LUBRICATION OF GAS AND GASOLINE ENGINES.

In the last few years gas and gasoline engines have come into very general use, and furnish power for a great variety of purposes.

The low price and availability of natural gas in Western Pennsylvania, Eastern Ohio and West Virginia make the gas engine a very economical source of power in those districts.

There are a great many different makes of gas and gasoline engines on the market, but the principle on which they all operate is about the same. The power is derived from the explosion in the cylinder of a gas or gaseous vapor, combined with air, and is ignited by a flame or an electric spark.

The continual ignition and explosion of the gas in the cylinder generates an intense heat, and to keep the temperature at as low a point as possible the cylinders are usually surrounded by a water jacket through which cold water is kept circulating; but notwithstanding this the temperature of the interior of the cylinders reaches a very high point.

With the horizontal type of gas engine lubrication is necessary to reduce the friction of the piston and its rings on the cylinder walls, and for this purpose a pure petroleum oil of from 26 to 28 gravity B′., 400 to 475 flash test, and a viscosity of 175 to 200 (Tagliabue) should be used.

If too low in flash test the oil will not remain on the surfaces long enough to afford any lubrication, but will vaporize as soon as it touches the heated surfaces; if too high in flash test, or if compounded with animal fats, it will carbonize and form a hard crust or coating of burnt oil in the piston rings and around the discharge valves and interfere with their operation.

The temperature of the firing end of a gas engine at the point of ignition is about 1800 to 2000 degrees, and no oil can withstand this temperature; so what is needed is an oil that will not burn or vaporize easily, that will spread quickly and keep the metallic surfaces apart, and when it does burn up or vaporize will do so without leaving any deposit.

It should be remembered that gas engines do not require as much cylinder oil as steam engines of the same size, for the reason that with a gas or gasoline engine the heat is a dry heat, and not moist, as is the case with a steam engine, which has a tendency to wash off the oil from the surfaces, it is safe to say that one quarter or one third of the amount required in a steam engine cylinder will be ample in a gas engine of the same size.

In the lubrication of gas engines of the vertical type, such as the Westinghouse gas engine, conditions are somewhat different from the horizontal type, in that no oil is needed in the cylinders. These engines are of the enclosed crank-case type, and the oil in the crank-case being continually splashed by the action of the cranks is thrown against the piston when it is at the bottom of its stroke, and conveyed by the piston up and over the cylinder surfaces, thus affording all the lubrication that is necessary. Being vertical engines, there is not the weight of the piston dragging on the bottom of the cylinder as is the case with the horizontal engine.

With this type of engine particular attention must be given to the lubrication of the journals and crank-pins. These are inclosed in a crank-case, and the oil for lubricating the wearing parts must be suitable for the work. It must be so high in flash test that it will not become too thin or vaporize when heated, because after several hours' running the oil in the crank-case becomes quite hot.

If too heavy the oil is apt to become thick and will not spread freely over the wearing surfaces.

When preparing to start a Westinghouse or other vertical type of gas engine, first see that the bottom of the crank-case is clean and free from dirt and grit, then fill the case with suitable oil until the end of the crank-pin bolts and the jam nuts dip into the oil about half an inch when the crank is on the bottom center. The height of the oil can then be noted in the open end vertical pipe outside the crank-case, and it should always be kept to this same height. A wooden or wire gauge can be made and inserted occasionally to see if it is at the proper height.

If the oil is too high in the crank-case it will be thrown with such force and in such volume against the piston and cylinder walls as to cause it to work past the rings, and getting on top of the piston it will be ignited, and in burning form a hard crust of carbon which will insulate the igniter points, so that the electric spark will not form and explode the gas, thus causing the engine to stop. When the oil is kept at the proper depth it is thrown in a fine spray over the journals and crank-pins, keeping them continually flooded.

It is a good plan to take out the igniter heads every few days and examine the igniter points, and if there is any trace of burned oil on them, clean it off.

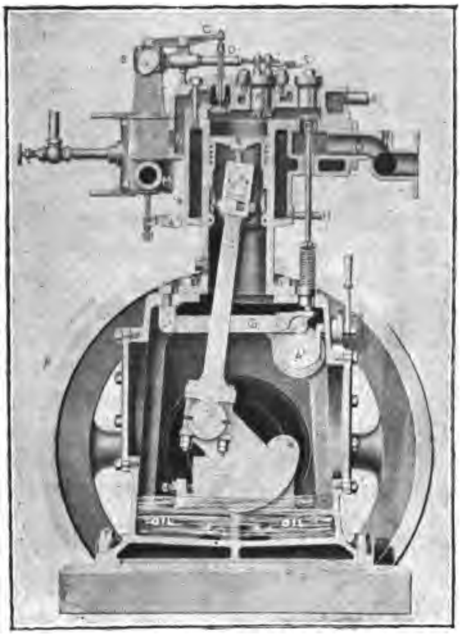

Fig. 28. Showing Lubrication of Vertical Gas Engine.

If the crank-case oil shows any tendency to become thick under continual use, it is a good plan occasionally to draw off a few gallons and replace it with fresh oil.

If the engine gives off smoke in any quantity it is an indication that the oil is working past the piston rings and getting on top of the piston and burning there. This may be due to there being too much oil in the crank-case, or that the piston rings are loose or broken, or that the cylinders are not kept cool enough.

LUBRICATION OF AIR COMPRESSOR CYLINDERS.

The use of compressed air is becoming so general that a knowledge of the principles governing the compression of air and the points to be looked after in the lubrication of the air compressing cylinders is of the utmost importance to the steam engineer.

The compression of air from a lower to a higher pressure results in the conversion of energy into heat, and the temperature increases with the pressure, but not in the same ratio. Air is considered as being formed of minute particles or atoms, and the compressing of a volume of air into a smaller space causes these atoms to increase their vibratory motion and the resultant friction and impact generates heat.

The rise in temperature of a volume of air due to its compression follows certain laws, and tables have been formulated which will show the theoretical temperature that the air will attain when compressed to various pressures. The following table shows the temperature that the air will attain, taking at the inlet at 60 degrees Fhr., and compressing it to various pressures:

TABLE XI.

Temperature at Inlet 60 Degrees Fhr.

Gauge Pressure. Pounds.	Degrees. Final Temperature.
25	234
50	339
100	485
125	540
150	589
200	672

The following table shows the temperature attained with various initial temperatures when compressing air to 100 pounds gauge pressure:

TABLE XII.

Initial Temperature. Degrees.	Final Temperature. Degrees.
Zero.	375
32	435
60	485
100	556

But in actual practice these temperatures are not attained, for the reason that in the economical operation of air compressors it is very important that the temperature be kept to as low a point as possible, and the compressing cylinders and the cylinder heads are provided with spaces through which cold water is kept circulating so as to absorb as much of the heat as possible. Where the air is compressed through more than one cylinder the temperature is still further reduced by passing it through what are called intercoolers, on its way from one cylinder to another.

These intercoolers consist of chambers or cylinders of cast-iron connecting the discharge of one cylinder to the inlet of another cylinder, They contain a number of small tubes through which the air passes and over which cold water is kept circulating. The heat due to compression that was not taken up by the water jackets around the cylinders is then absorbed, and the air is thereby prevented from reaching too high a temperature.

Air compressors used in the compression of air for use in mining machines, drills and other machines, are usually of the single-cylinder and duplex or two-stage type, in the single-cylinder machine the air is compressed to the desired pressure in one cylinder, while in the double-stage machine the air is first compressed to 35 or 40 pounds in one cylinder, from whence it flows to the second cylinder, where it is then compressed to 100 to 150 pounds per square inch.

There are also what are known as three-stage and four-stage machines in which the air is passed successively through three or four cylinders, in each of which it is compressed to a greater pressure than in the preceding one. In these cylinders the air is often finally compressed to 600 or 800, and in some cases as much as 2,000 pounds per square inch.

In a single cylinder machine taking air at 60 degrees and compressing it to 100 pounds pressure the air at the discharge will be theoretically 485 degrees, but the water jacket will take up part of this heat; even then, however, the actual temperature will often exceed 400 degrees, depending on the speed of the compressor and the temperature and velocity of the jacket water. In the two-stage machine the air is compressed in the first cylinder to about 30 or 40 pounds, and a discharge temperature of 200 to 250 degrees, from whence it flows through the intercooler on its way to the second cylinder, and the temperature is reduced to 80 or 90 degrees. The second cylinder takes the air at 30 or 40 pounds and compresses it to 100 or 150 pounds, with a resultant temperature of only 200 to 275 degrees. This same plan is carried out in the three and four-stage machines, the temperature being reduced in each intercooler without loss of pressure until finally the air is discharged from the last cylinder at a very high pressure and a comparatively low temperature.

In lubricating the interior of an air compressor cylinder the existing conditions are different from those found in a steam engine cylinder, in that the heat is a dry heat, while in a steam cylinder moisture is always present to a greater or less degree, and this moisture has a tendency to wash the oil off the surfaces, while in the case of air compressor cylinders the heat is dry and the oil adheres to the surfaces better and longer so that not so large a quantity of oil is needed to keep the wearing surfaces lubricated as would be required in a steam cylinder of the same size.

But owing to the intense dry heat to which the oil is subjected it must be of such a nature that it will not volatilize or form a coating of carbon or burnt oil in and around the discharge valves of the compressor.

If too low in flash test the oil on reaching the interior of the highly heated cylinder will vaporize and pass out with the air without affording any lubrication to the wearing surfaces.

If the oil be too dense or is compounded with animal or vegetable oils, as is the case with many steam cylinder oils, it will have a tendency to adhere to the discharge valves and passages, and being subjected to the dry heat of the compressed air will gradually change to a hard brittle crust or layer of carbon, which in time will completely choke up the air passages and render the valves inoperative.

It has been found by numerous experiments that where the temperature of the air reaches 350 to 400 degrees Fhr. a pure petroleum oil of from 500 to 530 degrees flash test, and of medium viscosity, will give the most satisfactory results; and where the temperature of the air does not exceed 300 degrees a more limpid oil and of lower flash test can be used, say of 400 to 425 flash test.

It is very important that the air suction or intake pipe be placed so as to secure air that is clean and free from dust and dirt, as any dirt that is sucked into the compressor with the air will have a tendency to adhere to the oily surfaces and form a sticky gummy mass, which in time will interfere with the operation of the valves. Complaints are often made regarding the quality of the oil when the trouble is really due to the dirty air.

Most cases of complaint in regard to the formation of coke or carbon come from the users of single-cylinder air compressors of small size, and of the spring valve type. These machines are often driven beyond their rated capacity, the temperature of the air will often go above 400 degrees, and the tendency of the attendants is generally to use more oil than there is any need of. It is the surplus oil that gathers around the valves and in the passages and becoming burnt causes the trouble.

A very little oil of the proper kind is required, for a single cylinder of 12 inches in diameter or less; a half a pint per 10 or 12 hours should be sufficient. If the valves are operated mechanically, that is by means of cranks or eccentrics, a little more oil may be needed.

With the two, three and four-stage compressors there is seldom any complaint in regard to the lubrication, as they are usually in the care of competent engineers; and if the water is kept flowing through the water jackets the temperature of the air seldom reaches a point that will affect the oil.

LUBRICATION OF COMPRESSED AIR MACHINERY.

The internal moving parts of machinery operated by compressed air, such as mining machines, compressed air locomotives, drills riveters, etc., are usually small and light in weight, but as they are operated at a very high rate of speed and their efficiency depends greatly on the closeness of fit of the parts it is very essential that they be kept well lubricated.

As air in expanding from high pressure to a lower pressure absorbes heat from the surrounding metal it will cause intense cold so it is necessary that the oil used will be of low cold test, for if it congeals it will have a retarding effect on the moving parts.

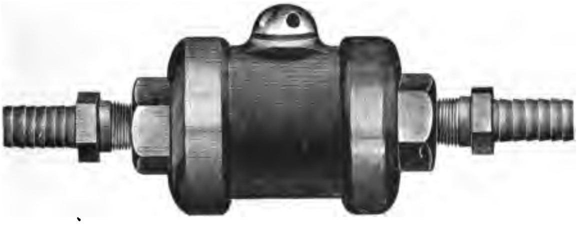

Fig. 29. Pneumatic Tool Lubricator.

Oil for this purpose should be of pure petroleum of about 30 to 31 gravity B'., a cold test of not more than 10 or 15 degrees and a viscosity of 150 to 200 (Tagliabue's instrument).

Figure 29 shows cut of a device for lubricating pneumatic tools manufactured by Messrs. A. M. Carron & Co., this appliance is attached directly to the air supply hose, it can be so adjusted as to feed any desired amount of oil, and only feeds when the tool is in operation.

LUBRICATION OF LOCOMOTIVES AND RAILWAY CARS.

Probably the lubrication of no other class of machinery has received so much intelligent and careful attention on the part of experts as that of railway locomotives and cars. The existing high degree of efficiency and freedom from hot bearings has been attained by a systematic and scientific attention to the composition, condition and fit of the bearing metals, the size and condition of the journals, the quality of the oil and packing used and a constant inspection and attention to their condition.

The annual oil bill of a large railway system is a big item, yet there is probably no other class of machinery in connection with which the cost per 1,000 or per million journal revolutions, or per 1,000 feet of piston travel is so low as that of railway rolling stock.

In the matter of cylinder and valve lubrication continued experiments have enabled the master mechanics and engineers to determine the exact amount of oil necessary to give the required results on each type of locomotive, and an allowance per day or per 100 miles traveled is made, based on these experiments. The same plan is followed out in regard to the engine oil, and a cost account is kept with each locomotive, so that at the end of each month the reports will show just what it has cost for each locomotive per 100 miles traveled.

Many types of stationary engines are so arranged that a very large percentage of the oil can be caught and filtered and used again. But with locomotives the oil once used is gone forever, yet there are very few engines on which the loss or wastage of oil for the amount of duty performed is so slight as on locomotives.

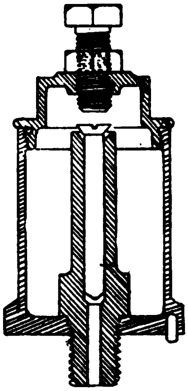

Fig. 30. Locomotive Oil Cup.

The principal reason for this low oil consumption is due to the fact that the oil cups used are so constructed as to feed very small amounts of oil continuously while the engine is in motion, and stop altogether when the engine stops. Fig. 30 shows a sectional view of a locomotive rod cup. As will be seen it consists of a receptacle fastened to the connecting rod and parallel rods above the pins, containing an inner tube in which is placed a piece of wire slightly smaller in diameter than the tube; this is so arranged, by means of an adjustable screw, that the wire will have a certain amount of lift or throw, due to the motion of the rods to which the cups are attached. The oil splashes against the wire and adheres to it, and is carried by the up and down motion of the wire down onto the crank-pin. This arrangement admits of very close adjustment, so as to feed as little or as much oil as may be necessary, provided that the quality of the oil be kept constant and not susceptible to changes of temperature.

Many of these cups only contain about a gill of oil, yet often not one-half of that quantity will be used by a fast passenger locomotive in a run of 100 or 150 miles, and the pin will be kept perfectly cool.

Another and very important reason for economy in oil consumption in locomotive practice is the fact that the brasses are either solid or kept fitted "brass to brass." In stationary engine work it is usually the custom to fit the brasses with a space between their edges of one-eighth to three-eighths of an inch, and in consequence, the oil is thrown out or drops out about as fast as it goes in, while on locomotives the close fit of the brasses tends to retain the oil in place, and it remains on the wearing surfaces longer. In fact it can only escape at the end of the brasses and pins.

The allowance of oil for locomotives will vary on different roads and with the duty they have to perform. The Pennsylvania Railroad Co. allow on their heavy passenger locomotives four pounds of valve oil and ten pounds of engine oil per locomotive, from Pittsburg to Altoona and return, a distance of 234 miles. This allowance of valve oil lubricates the two main engine cylinders and their valves and seats, and also the steam cylinder of the air brake pump, while this allowance of engine oil serves to lubricate all the bearings, which on a fast passenger engine include four main driving boxes, four forward truck wheel boxes, four eccentrics, four guide bar cups, two cross-head cups, two crank-pin cups, four parallel rod cups and all the small bearings on the links and valve motion.

Mr. D. J. Redding, Master Mechanic of the Pittsburg & Lake Erie Railway Co., who has given the subject of locomotive and car lubrication a great deal of attention, and has been successful in obtaining very economical results, informs the author that during 1901 the consumption of oil on passenger engines on this road averaged one pint of valve oil for each 120.3 miles traveled, and one pint of engine oil for each 58.8 miles traveled. In freight service the locomotives made 46.7 miles per pint of valve oil, and 34.2 miles per pint of engine oil, and the average oil cost for both oils for both freight and passenger locomotives during the year was 15 cents per 100 locomotive miles.

The driving axle boxes of locomotives support the weight of the boiler and its fittings; in stationary engine practice the length of a bearing is from one and one-half to two times its length, but owing to existing conditions in locomotive practice, such as the width of the fire-box, distance between cylinder centers, and gauge of the track, the driving axles or journals are made as short as possible, usually only very little longer than their diameter; a locomotive whose journals are 8 inches in diameter are about 9 inches long; one whose diameter in 6¾ inches have a length of 8 inches, and one whose diameter is 5½ inches is 6¾ inches long.

The journals are usually so proportioned as to sustain a maximum load not exceeding 175 to 200 pounds per square inch of projected area In stationary engine practice the weight of the shaft is on the bottom of its bearing, and the oil will flow by gravity to the point of greatest pressure, while with a locomotive driving axle the weight comes on the upper half of the driving box, and the greatest care must be taken in regard to its lubrication.

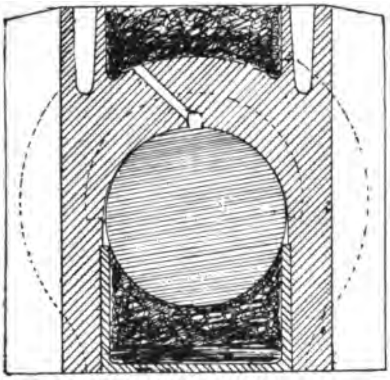

Fig. 31. Locomotive Driving Box, Showing Oil Cellars.

Figure 31 shows side view of a locomotive driving box. The outer part or casing is made of cast-iron, the inner shell of which is of phosphor-bronze or other hard bearing metal. Sometimes it is lined with babbitt metal, or fiitted with strips of babbitt inserted into longitudinal grooves in the crown of the brass, though some claim that babbitt should not be used for this work, as the grit which will enter in spite of all precautions will become imbedded in the soft metal and tend to wear the journals very rapidly, and that therefore a hard bronze should be used instead.

As the weight of a driving axle is often over 9,000 pounds and the surface travel of the journal on a fast passenger engine will often exceed 600 feet per minute, it is very essential that great care be taken with their lubrication. Mr. Redding makes a practice of renewing the waste in the cellars of passenger engines every week and of freight engines every 30 days.

In the matter of car lubrication it is more a matter of constant and careful inspection than of quality or quantity of the oil used in order to secure freedom from hot boxes, although the quality of the oil should be of the best and the quantity should be sufficient. In fact, to such a degree is this true that it is a well-known axiom among railroad men that of two roads using the same grade of oil, waste and bearing metal, that road on which the inspection is the most thorough will have the least number of hot boxes and the lowest cost per car mile.

A railway car journal box is one of the simplest and at the same time most efficient appliances there is for lubrication. It consists of a square cast-iron box on the truck frame, which fits over the journal and supports the weight of the car; on top of the journal is placed a "brass," which is composed of an especially tough anti-friction metal, so that it will withstand the shocks and pressures due to heavy loads and high speeds, with as low a per cent. of friction as possible. On some roads it is the practice to line the wearing surface of the brasses with a thin coating of lead, the lead being soft and yielding, and at the same time of good anti-friction value, will squeeze out and wear down quickly, so as to conform to the inequalities of the journal surface, so that the weight is soon distributed evenly over the whole wearing surface, thus insuring a cool running bearing from the start.

The box is then packed with a good grade of long fibre wool waste, which has been thoroughly soaked in oil. The action of the waste is to absorb and retain the oil by capillary attraction, and the journel in revolving in contact with the waste takes up the oil and conveys it between the bearings and the journal.

The oil should be of a grade especially adapted for this work; it should have sufficient body or viscosity to cause it to adhere well to the journal and bearing surfaces, and keep them apart. The flash test should be high enough so that the oil will give off no inflammable vapors under ordinary running conditions, and that it will retain its body when subjected to ordinary frictional heat. It should be fluid enough so that the fibres of the waste will take it up readily by capillary attraction, and, what is very important, it should be of low cold test, so that it will not congeal in cold weather, as the power required to move a heavy train in the journal boxes of which the oil has become congealed is many times greater than if the oil was in a fluid state.

In regard to oils it may be said that the cost per gallon is the least important factor as compared with the cost of repairs, renewal of wearing parts and delays. A hot box means excessive friction and costs money at the coal pile for every mile that the car is moved; it costs money to replace wornout bearings and to turn down or to renew car axles, and all other conditions being the same, the oil that will prevent wear the most is by long odds the cheapest to use no matter what the cost per gallon.

Hot boxes may be due to several causes, among them are the over-loading of the cars, especially the older makes of cars which have small journals and light brasses, the entrance of dust and grit caused by the covers of the boxes being broken or lost, or the dust guards getting loose, allowing the oil to leak away and leaving the waste packing dry; or the brasses may not fit the journals properly, causing the weight to be unevenly distributed and creating excessive friction on the high spots; or the oil or packing may be of poor quality. Any one of these if not promptly attended to is apt to cause heating, and the exercise of constant and intelligent care in these matters is the price of success.

The benefits and economy to be derived by a close attention to the details of inspection and lubrication in railway work has been graphicaly described by Mr. J. N. Barr, formerly superintendent of motive power for the Chicago, Milwaukee & St. Paul Railway Co., in a paper presented at a meeting of the Western Railway Club, of Chicago, in November, 1892.

He states "that the Chicago, Milwaukee & St. Paul Railway Co. had used since 1884 and up to the present time (November, 1892) but one kind of oil on its freight cars, and the cost of oiling in 1885 was 27.76 cents per 1,000 car-miles, and that the number of hot boxes and the loss in delays and repairs had become excessive, and a personal inspection showed that the trouble was not due so much to lack of quantity or the quality of the oil as to a lack of proper inspection on the part of the men whose duty it was to attend to this work."

"Cars were found with broken box lids, loose dust guards, boxes filled with dirt and sand, insufficient amount of waste in the boxes, improperly fitted and worn out brasses, so that no matter how much oil was used the result was the same."

Rules were issued to the men in charge of the oiling stations in regard to the inspection of the car boxes, and a careful supervision was kept over this work by competent men, a record was kept of the number of hot boxes reported, repairs made, and the amount of oil and waste used. This information was tabulated so as to show the cost per 1,000 car miles on each division of the road. As the result of this work the cost was reduced from 27.76 cents to 14.76 cents per 1,000 car miles, and the total saving on the oil bill in 1891 as compared with previous years amounted to $35,000, and there was a large decrease in the number of hot boxes besides.

But in more recent years, owing to the progress made in the economical lubrication of railway cars, the cost has been reduced far below the above-mentioned figures. Mr. Redding, Master Mechanic of the Pittsburg & Lake Erie Railway Co., reports an oil cost during 1901 for passenger cars of 3.287 cents per 1,000 car miles, and for freight cars of 4.795 cents per 1,000 car miles; and when one considers that there are eight journals under an ordinary passenger coach, and the trains often attain a speed of 60 miles an hour on this road, and that a car would travel nearly 3,500 miles at a cost of one cent for oil, per journal, one realizes that the system of lubrication and inspection must be about as perfect as can be obtained.

Mr. Redding also states that the monthly consumption of oil and waste for packing the locomotive tender boxes was 15 gallons of oil and 15 pounds of waste for 150 locomotive tenders, each averaging over 130 miles a day, and as an experiment the journal-boxes of the tender of a fast passenger engine was packed with oil soaked waste, and ran 130 miles every day for eight months without being re-packed or a drop of oil supplied to the boxes, and without a hot box during that time, but before each trip the waste was lifted and stirred with the packing tool to prevent it from sagging down and away from the journals.

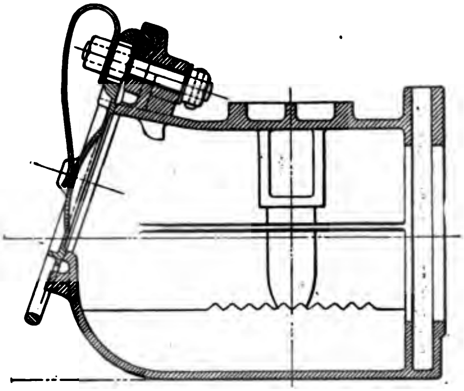

Fig. 32. Symington Car Journal Box. Side View.

Figure 32 shows an improved form of car journal box, the invention of Mr. T. H. Symington, which combines to a high degree the two prime essentials of a perfect journal box, namely, to keep the oil in and to keep the dirt out. As will be seen in Fig. 33, the front of the box is machined and fitted with a machine faced lid which is held in place by a stiff spring against the face of the box, at the back of the box in a groove or slot is placed a dust guard, which fits snugly around the axle and prevents the oil from leaking out, and also makes a tight joint against the back of the slot and prevents the entrance of dust.

Extending along the inside of the box and parallel with the journal are four projections or ribs, which extend inward toward the journal, as will be seen in Fig. 33. The two upper ribs serve to prevent the waste from being packed too high in the box, as, if too high, it is apt to be caught by the revolving journal and carried up under the brass and throwing it out of its proper position causing it to heat.

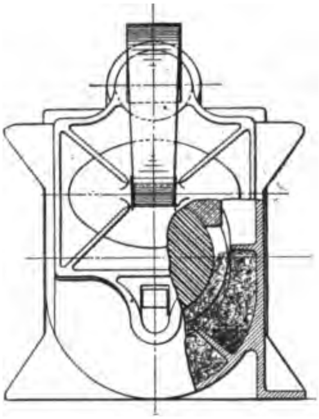

Fig. 33. Symington Car Journal Box. End View.

The two lower ribs are inclined and hold the waste up against the journal, preventing its rolling or settling in the box, and their inclined position forms a reservoir to retain some of the oil and helps to keep the waste well saturated.

DIRECTIONS FOR THE LUBRICATION AND INSPECTION OF RAILWAY CAR JOURNALS.

The following rules were formulated for the guidance of car inspectors, repair men and others by Mr. Chas. E. Ward, oil inspector in charge of lubrication for the Pittsburg Coal Co., and formerly traveling inspector in the car service department of the Chicago and North Western Railway Co.

These rules are equally applicable to electric traction roads.

TO MASTER MECHANICS, FOREMEN AND INSPECTORS.

In the work involved in lubricating freight and passenger cars, and in the changing of wheels under all classes of equipment, the following instructions, as far as practicable, must be carried out:

1st. The journals of all wheels put into service must be thoroughly cleaned and smoothed, and a little clean oil applied over the entire surface of the journal before it is put in. In the changing of wheels new brasses must at all times be used, except at such places as are provided with the necessary machines for re-facing the old brasses. Where old brasses must be re-faced, put them into the machine and face to the size of the journal on which they are intended for use. These may be used on any class of equipment. New dust guards must in all cases be applied where wheels and axles are changed.

2nd. A brass that has run warm or hot should always be sent to the shops as a condemned brass. Under no circumstances should they be turned up and put into service again.

3rd. In the packing of oil boxes, waste intended for that use should be soaked in oil at least 36 hours before it is put into the boxes. After it has soaked in liquid oil for 24 hours, it should be raised up above the oil to enable it to drain and allow the loose oil to flow out of it. Care should be taken to see that there is always enough oil in the waste, and yet it is not intended that there should be so much that it would flow out of its own weight. Too much oil causes the waste to become soggy and decreases its elasticity.

4th. To secure good lubrication, the packing must be put into the boxes in sufficient quantities to keep it in close contact with the journals, but in no case should it be packed so high as to come in contact with the brass.

5th. To secure a uniform method of lubricating journals, the following method of packing boxes should be observed: The first packing applied should have the free oil pressed from it, and then be placed in one piece to the extreme back end of the oil box, and firmly packed with the iron close to the back end of the box and up to and around the lower half of the journal. This is intended to close the opening tight around the dust guard, and prevent sand and dust getting into the box and the oil from getting out. The packing from the back end of the box, to the front end of the journal, should be saturated with oil and placed firmly against the journal, extending no higher than the center of the journal. The packing placed in the box in the front of journal should be put in one or two large wads and should have no thread connections with the waste under the journal.

6th. Persons engaged in the lubricating of cars must carry a packing iron and hook for the removal of waste. They must remove all surplus waste from the oil boxes, and after thoroughly working it up, should it be found dry, sufficient oil should be applied to properly lubricate the journal. All surplus packing removed must be returned to the oil house, where it should be carefully picked over, removing and destroying those parts not suitable for future use, and re-saturating that which is. In the case of condemned waste, where it is possible, it should have the free oil squeezed out and put back into use again, before the waste is destroyed.

7th. In the use of liquid oil along the line, oil cans with small spout ends should be used, and a small quantity of oil put well back toward the center of the journal on the rear side of the box, which insures the oil feeding up towards the brass. Under no circumstances should oil be poured along the end of the journal.

8th. In all cases where one box on a truck is oiled, a careful examination of the balance should be made to determine their condition, and the trucks should be marked with the date when the oiling was done. This in intended as a guide for the oilers at the next station.

9th. When packing is carried in buckets, covers should be provided to prevent the dust and dirt from getting into it.

10th. When cars are taken into trains at outlying points, or junction points, where there are no car repairers or inspectors, the train men are expected to open all the oil boxes and with packing iron work the packing up so as to be in close contact with the journal, to prevent the same from heating before they reach such stations where proper care can be given them by the regular oiling force. In all cases where cars are so taken, the train men should report them to the car inspecting force, so that special care may be given them in the matter of oiling.

11th. Sufficient time should always be given the inspectors and oilers to see that car journal boxes are in good condition. Where this cannot be done, reports should be made to this office, that other arrangements may be made for the care and attention of the cars while in transit.

12. Oil barrels and receptacles for the storage of oil must be left covered, clean and in an orderly condition. Drip pans must always be provided for the drippings, and care taken to prevent the oil from spreading over the floor of the oil house, causing danger from fire.

13th. These instructions are given as a general guide for the lubricating of oil boxes, and it is expected that all persons interested therein will exercise the greatest care in the oiling of cars and in their attention to the oil held in stock by them.

LUBRICATION OF AUTOMOBILES.

Automobile engines, whether run by steam or gasoline, are usually provided with casings so arranged as to hold a supply of oil in which the cranks revolve, and all moving parts are lubricated by the spray of oil thrown over them by the cranks.

Oil for use in the crank-cases should be of pure petroleum, free flowing, and of low cold test, and at the same time sufficiently high in evaporative test as not to give off any vapor when subjected to frictional heat or when coming in contact with the cylinders and other heated parts.

For steam operated vehicles a good grade of cylinder oil should be used; as these engines are small but very little oil will be needed. A small force-feed lubricator will give the best results, as being connected directly to the engine they will commence to feed as soon as the engine starts, and stop feeding when the engine stops.

For gasoline engines which have their cranks enclosed no oil need be fed to the cylinders, as the cranks will throw sufficient oil onto the exposed end of the piston trunk, which will draw it up onto the cylinder walls so as to keep them well lubricated.

Care should be taken not to have the crank-case too full of oil, for if it is the oil is thrown against the piston trunk in such volume and with such force as to cause it to carry past the piston rings and to get on top of the piston when it will come in direct contact with the intense heat of the exploding gases and will burn and form a coating of carbon that will cause trouble and finally disable the engine.

Where the engine is not enclosed in a case a multiple oiler should be used; by means of this each bearing can be given the necessary quantity of oil independently of the others.

Transmission and speed change gear-cases should be kept filled with a good quality of medium bodied machine oil; if the gear-case leaks and cannot be made tight a good grade of soft grease may be used.

LUBRICATION OF STREET RAILWAY CARS.

The journals of street railway cars can be lubricated best and most economically by adapting the same methods used with steam railway cars.

Some types of car journal boxes are provided with a pair of felt pads so arranged that the upper ends are in contact with the journal surface while the lower ends dip into the oil in the oil chamber; the oil saturates the pads by capilliary attraction and the journal by rubbing against the pads carries the oil to the bearing.

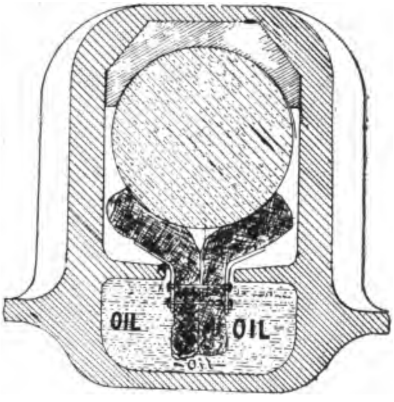

Fig. 34. Street Railway Journal Box.

Figure 34 shows a sectional view of this type of bearing.

Oil for this purpose should be thin and limpid so as to saturate the pads freely, and of low cold test so it will not congeal in cold weather; a good dynamo oil will usually do nicely. Care should be taken that the dust guards at the back of the box are kept tight to prevent leakage of the oil.

But recently traction road managers are adapting steam railroad methods in regard to lubrication, packing the boxes with wool waste that has been soaked for 36 or 48 hours in a good quality of car oil.

Grease has been used quite extensively on electric car journals, but with the advent of a heavier car running long distances at high speeds it has been found that there is less friction and wear of brasses and journals by the use of oil, although grease is used on the motor bearings for the reason that owing to close proximity to the armature, oil would get on the coils and soak through and destroy the insulation; for these bearings a soft grease that will feed down freely and that will not leave a hard crust or residue should be used.

AN ACT.

COMMONWEALTH OF PENNSYLVANIA.

No. 263.

Making the wilful and malicious taking or removal of the waste or packing from out any journal-box or boxes of any locomotive, engine, tender, carriage, coach, car, caboose, or truck, used or operated upon any railroad, whether the same be operated by steam or electricity, a felony, and providing penalties therefor.

Section 1. Be it enacted, etc., That if any person shall wilfully and maliciously take or remove the waste or packing from out any journal box or boxes of any locomotive, engine, tender, operated upon any railroad, whether the same be carriage, coach, car, caboose or truck, used or operated by steam or electricity, the person so offending shall be guilty of a felony, and on conviction be sentenced to pay a fine not exceeding five hundred dollars and to undergo an imprisonment by separate and solitary confinement at labor, not exceeding five years, or both, or either, at the discretion of the court.

Approved the tenth day of June, A. D. 1901.

WILLIAM A. STONE,
Governor.

The foregoing is a true and correct copy of the act of the General Assembly No. 263.

W. W. GRIEST,
Secretary of the Commonwealth.

LUBRICATION OF MARINE ENGINES.

In the lubrication of marine engines certain conditions prevail which do not exist on stationary or locomotive engines. In the first place, being vertical engines there is not the weight of the piston dragging on the bottom of the cylinders, as in the case of locomotives and most stationary engines, and therefore there is less frictional wear between the piston and the cylinder walls, and very little cylinder oil is needed.

Steamers plying in salt water are provided with surface condensers and the condensed water is pumped back to the boilers, and as it is very important that the condenser tubes and the boilers be kept as free from oil as possible, the less quantity of oil used in the cylinders the less there will be to go to the boilers.

Therefore, whatever oil is used should be of the best quality, either of pure petroleum, or with a very small percentage of animal fats. A pure petroleum oil is more easily separated from the condensed water, while the animal oils will emulsify with the water and be hard to separate.

On account of the annoyance caused by inability to filter out the oil and the accumulation of it in the condensers and boilers many engineers have discarded the use of cylinder oil altogether, especially on the smaller size engines.

In the United States Navy the boilers of the torpedo boats, torpedo boat destroyers and other small high-speed craft, are usually fitted with water-tube or coil boilers and disastrous results have occurred by the oil adhering to the inner surface of the tubes which were subjected to the intense heat from the forced draft. For this reason cylinder oil has been discarded entirely from this class of boats, and tests have shown that there is very little if any increase of cylinder and valve friction.

Modern marine engines usually have their pistons fitted with light cast-iron snap-rings, made from a grade of iron softer than the cylinder castings, and sprung into grooves in the piston with a tension against the cylinder walls of only their own elasticity.

These rings fit into grooves in the pistons and while they bear but lightly against the cylinder they do so sufficiently to prevent the steam from blowing past them. Some engineers claim that all the oil that is needed is just a little before the engines are stopped, so as to prevent the surfaces from rusting.

In regard to the external lubrication of modern marine engines, it is usually customary to supply the oil to the various bearings by means of a reservoir and a system of sight feeds and small pipes leading to the various bearings and journals, so that the proper amount of oil supply can be given each bearing according to its needs.

In modern marine engine construction many refinements and conveniences exist as regards the lubrication of the bearings. The main shaft bearings are sometimes cored and provided with pipes so that water can be kept circulating through them all the time that the ship is in motion, so as to absorb any frictional heat as fast as it is generated. Some engineers claim that these water jackets should only be used when there is a tendency to heating of the bearings, and argue that a large quantity of cold water flowing through the pipes prevents any rise of temperature from becoming known in time to prevent damage to the bearings; and they contend that the water should only be allowed to flow through just so fast, that if there is any incipient heating it will be noticeable in the rise of the temperature of the water flowing from the bearings. Prompt measures should be taken to loosen the bearing if too tight, or do whatever else may be needed to prevent excessive heating. Heat in a bearing is evidence that the condition of the bearing and journal is not what it should be, and the water jacket may easily become a means of preventing it from becoming known that the surfaces are not in perfect condition.

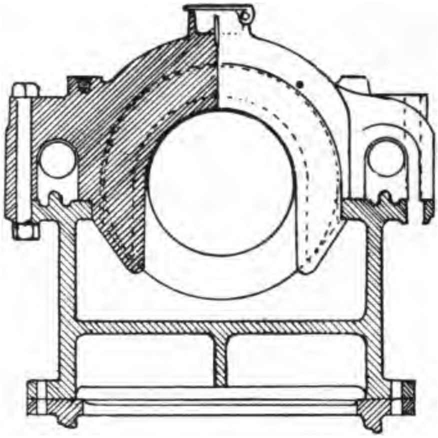

Fig. 35. Marine Engine Thrust Bearing. End View.

The guides are also cored to form a water space so that water can be used to absorb the heat of the cross-head and guides. Sometimes the crank pits are cased with sheet steel drip-pans to catch the oil that drips from the pins and bearings and prevent it going into the bilges and being pumped overboard with the bilge water. These pans are arranged with strainers and pipes so as to convey the oil to a tank located below the level of the bed-plate, where the water has a chance to separate and the oil is pumped to a filter and after being filtered is used over again.

One of the most important bearings on a ship and sometimes the most difficult to keep cool, is the thrust bearing. This bearing is secured to the frame of the ship abaft the engine, and takes the thrust of the screw; in fact the whole power of the engine in propelling the ship is exerted against the thrust bearing, as will be seen in Figs. 35 and 36. A thrust bearing consists of a metal case and cap containing a number of babbitted segments of rings or horseshoes, as they are called, separated by spaces. On the shaft are collars which fit into the spaces between the babbitted rings, and bear against

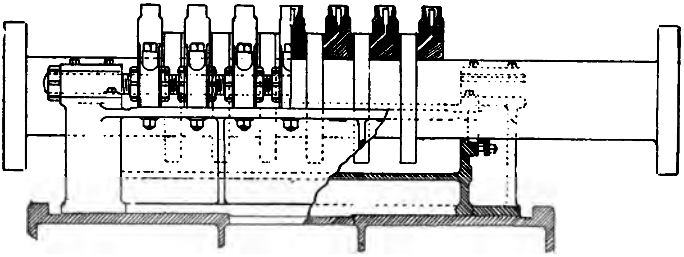

Fig. 36. Marine Engine Thrust Bearing. Side View.

them. The lower part of the bearing is so arranged as to form a chamber which will contain a supply of oil or oil and water, so that at all times the rings and collars are submerged in a bath of oil.

In the days of wooden steamers it was usually customary to keep a stream of water running on each bearing, and also on the crank-pins, and on the guides; and lard oil was used as a lubricant, as it would cling to the wet surfaces and form a soapy emulsion with the water; but since the advent of steel steamers with their greater rigidity and stiffness, the use of water has been done away with and pure petroleum or mineral oil has been substituted for lard oil.

One of the disadvantages of lard oil is its tendency to form verdigris wherever it comes in contact with brass or copper. This in time will clog the oil pipes and cups. It is, moreover, very poisonous when brought into contact with a sore or an abrasion of the skin. The author has a large scar on his hand caused by verdigris poisoning while cleaning out brass oil pipes.

LUBRICATION OF MINING MACHINERY.

There is probably no other class of machinery in which the principles of lubrication seem to be less understood by the men who operate them, or on which the oil is so recklessly wasted as on the machinery used in mines, and especially in coal mines.

One of the greatest items of expense around a coal mine is the car oil used to lubricate the spindles of the mine car axles. In the modern machinery equipped coal mine the distances that the cars travel is considerable, and the rate of speed and the length and weight of the trains which are hauled by electric or compressed air locomotives are such that any unnecessary increase of friction detracts very materially from the capacity of the locomotive.

With the old style wheel which is still in use at many mines the spindles required oiling every trip, and a very large per cent. of the oil would drip off before the car wheels had made a dozen revolutions, and at a large mine, where hundreds of cars are in use, the waste of oil due to carelessness in handling it at the oil house and while oiling the cars, is sometimes enormous, so that the less often the wheels require oiling the less the chances for wastage will be. No one but a good, careful man should be assigned to this work, and he should be provided with suitable cans, and care should be taken that the oil is not allowed to drip over the hubs of the wheels, or onto the track, when filling the oil chambers.

In the last few years several different makes of improved mine car wheels have come into use that are practically self-oiling. These wheels are provided with oil chambers in the hubs, which are intended to retain the oil and allow it to flow out gradually onto the spindles. Some of these oil chambers are partly filled with wool waste, while others have pads of felt through which the oil saturates onto the spindles.

As a general rule the oil used to lubricate mine cars is of a very poor quality and cheap in price, and the percentage of power absorbed by friction is considerable. With the old pattern mine car wheel it doesn't pay to buy a good quality of oil, for no matter how good the oil is, all but a very small per cent. is wasted by dripping off.

With the improved waste or felt-packed wheel that only needs an occasional replenishing, the oil should be of good quality, it should be thin enough so that it will saturate the packing freely, it should have body or viscosity enough to enable it to adhere well to the wearing surfaces, and it should also be of low cold test, so that it will remain fluid in cold weather.

Very often self-oiling wheels have been condemned for the reason that the oil used was too thick and of poor cold test. It would not saturate through the packing, and in consequence the metal surfaces came in direct contact and created undue friction.

Some makes of wheels forfeit their title to self-oiling for the reason that there is not sufficient means provided to prevent the oil from leaking out at the back of the hub, and if a thin oil is used it will soon leak away; and it will also allow the dirt and grit to work in and increase the friction and wear.

Among the types of wheels that most nearly fulfill the requirements in mine service is the Faught Patent Closed Hub Self-Oiling Wheel. The principles of its various parts will be seen by reference to the sectional views.

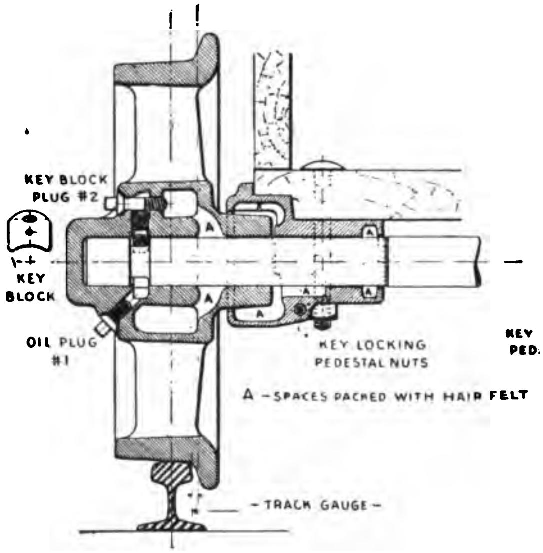

Fig. 37. Faught Patent Self-Oiling Mine Car Wheel.

The wheels, as will be seen in Fig. 37, are cast with an outer hub (A) which completely incloses the end of the axle. The inner hub enters a dust collar in the pedestal casting, which contains a broad band of hair felt which serves to exclude dirt and dust from the wearing surfaces, and also prevents leakage of the oil. At the inner end of the pedestal there is a smaller band of felt (A) which acts as a further protection against dust and leakage. The spaces in the hub are also packed with felt and the oil chamber is filled with oil through the hole (No. 1) when the wheel is turned so that the oil hole is above the axle.

The wheel is held in place by the key plug (No. 2), which fits loosely in the grooves in the hub and axle, and is held in position by a bolt.

With this type of wheel a good quality of free-flowing oil of low cold test should be used that will give perfect lubrication without liability of leaking out, and that will only need to be filled once in several weeks, instead of every trip or every day.

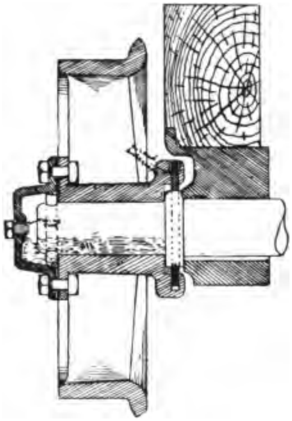

Fig. 38. Salmon Mine Car Wheel.

Fig. 38 shows another very efficient and economical self-oiling wheel known as the Salmon mine car wheel.

The wheel is held in place by the pin through the end of the spindle, the chamber in the hub is filled with oil through the hole at the center of the hub, at the back of the wheel is a close fitting collar which prevents the oil leaking out.

The Salmon mine car wheel. Fig. 38, is another very efficient wheel, as will be seen, the wheel is kept in place by means of a pin through the end of the spindle, the oil is poured into the chamber in the wheel through the hole at the center of the hub, a close fitting collar prevents the oil from working out at the back.

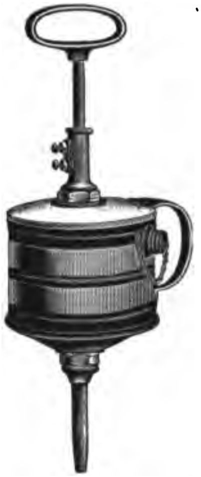

Fig. 39. Tormay Patent Mine Car Oiler.

One of the greatest factors in the economical lubrication of mine cars is to have the oiler provided with good cans. With the ordinary oil can, especially after it has been in use for a while and the spout has become broken, there is great waste of oil, and in the hands of a careless oiler often more oil is spilled on the ground than is put on the axles.

One of the best oil cans for lubricating mine car axles is the Tormay Mine Car Oiler (see Fig. 39), the invention of Mr. Tormay, Superintendent of the Trotter Works of the H. C. Frick Coal and Coke Co. This oiler is made of heavy galvanized steel, with a substantial iron spout, the spout is inserted in the oil hole in the hub of the wheel and the oil forced in by means of the plunger, which is so arranged that any amount of oil from a few drops to three or four ounces can be forced out at each stroke, and no oil can escape from the spout until another stroke of the plunger is made.

A large quantity of oil used on the coal cutting machines is wasted through carelessness on the part of the operators. These machines are run at a high rate of speed, in the dark, and are continually covered with coal dust. An oil suitable for this work should be quite heavy in body, the machine operator should be provided with small heavy steel cans, and a certain daily allowance, based on the experience of some good careful man should be made.

LUBRICATION OF REFRIGERATING MACHINERY.

In the operation of refrigerating machinery certain conditions exist which require that the oil used for lubrication shall be of such a nature that it can be subjected to quite a high temperature and to a very low temperature without congealing.

In the manufacture of artificial ice, or to speak more correctly, in mechanical refrigeration, the anhydrous ammonia gas is compressed in the compression cylinders to about 120 to 200 pounds pressure per square inch, according to the class of work done, and the requirements of the plant. It is then allowed to expand down to about 15 pounds in the expansion coils. In some types of machines oil is used to lubricate the ammonia cylinders and pistons and to fill the clearance space and to reduce the heat of compression, for in compressing the ammonia gas to the required pressure its temperature is raised to about 180 to 200 degrees. And the oil for this purpose must have a flash point so high as to not give off any great amount of vapor.

After the ammonia has been compressed to the proper extent it is allowed to flow through the expansion coils and thus produces the refrigerative effect.

All refrigerating plants are provided with a separator in the ammonia discharge pipe which is supposed to, and does to a certain extent, separate the oil and other foreign matter from the ammonia; but a certain quantity of oil will always go past the separator in the form of vapor and collect in the condensing coils, so that it is very essential that the oil be of such a nature that it will remain in a fluid state when subjected to low temperatures. If the oil be of poor cold test it will congeal and form a coating on the inside of the coils and tend to lower the efficiency of the system and eventually clog up the pipes.

An oil for this work should be of 30 gravity, of about 300 to 325 flash test, and stand a temperature of 5 degrees above zero without congealing.

Different makes of refrigerating machines have different requirements as to the use of oil. The De La Vergne machine is what is known as the double-acting type, and oil is used to fill the clearance space as well as to lubricate the cylinders and pistons. On some makes of machines the oil is only used in the space in the stuffing boxes on the piston rods, and none is fed into the compression cylinders; but no matter how tight the packing is kept some of the oil will work through into the cylinders and pass out with the ammonia gas; and notwithstanding the fact that the discharge pipes are provided with separators, some of the oil will pass through into the system.

In the lubrication of the steam cylinders of a refrigerating plant, especially where ice is made, certain points must be looked after that are not essential in any other class of engine.

It is customary in the manufacture of ice to condense the exhaust steam and purify it, and use it to make ice of; and for this reason the oil used for lubricating the valves and surfaces of the steam cylinders should be of pure petroleum or very nearly so; and it is well for the engineer in charge of a refrigerating plant to go on the theory that the less oil used in the cylinders the less there will be to separate from the condensed water. The steam cylinders of refrigerating machines are not as a rule very large, and the piston speed does not as a rule exceed 400 to 600 feet per minute, so that if a first class quality of oil is used very little will be required to give good lubrication.

In the process of making ice the exhaust steam first passes through a separator where the steam is relieved of some of the oil; from thence it passes to a feed water heater, where it imparts some of its heat to the boiler feed water, then it goes to the condenser and is condensed and the water of condensation is pumped to a re-boiler and skimmer; and any oil that has not been removed in the preceding processes is taken off, the water passes through the cooling coils and on to the bone dust or charcoal filters, where it is still further cleansed of its impurities, from thence it passes to the settling or sweet water tank, as it is called, and it is finally drawn off through a sponge filter on its way to the freezing cans.

From this it will be seen how important it is that the water be kept as free from oil as possible. If the oil contains any great amount of animal fats in its composition it will form a white milky looking emulsion with the water that will be very difficult to remove.

The presence of a yellow or reddish color in the ice is often attributed to the cylinder oil getting in the ice. This may sometimes happen when the oil is used too freely, or the filters are out of order; but as a general thing the stain is due to the presence of rust in the water. Condensed water has a very active effect on iron when combined with oxygen, and when the plant is shut down and the pipes are empty the action of the air on the moist pipes soon causes them to rust, and when the plant is started again, unless care is taken to prevent it, the rust will be deposited in the freezing cans.

LUBRICATION OF TEXTILE FABRIC MACHINERY.

Upon no class of machinery are the requirements such that a slight difference in the lubricating quality of an oil will be so seriously felt in the fuel consumption as in spinning and weaving machinery.

A cotton mill, for instance, besides having a large amount of ordinary shafting and machinery running at a high rate of speed, has a large number of spinning, weaving and other machines used in the manufacture of yarn, thread and cloth, no single one of which requires very much power to operate it, but in the aggregate they will consume several hundred horsepower, and in very large mills often over 1,000 H. P. As the friction loss in machinery of this kind where there are thousands of bearings, is very large and the journals and spindles are revolving at a high rate of speed, it is of the utmost importance that close attention be given to the details of lubrication, and that the oils for this work be of the very best quality.

The size or capacity of a textile fabric mill is generally known by the number of spindles it has in operation, and it is very essential in the economical operation of a cotton mill that the matter of lubrication of the spindles be properly attended to.

The spindles support the bobbins on which the yarn is wound, and are ranged on either side of a machine called a spinning frame, each frame containing from 160 to 224 spindles, which are driven at a speed of 8,000 to 12,000 revolutions per minute, according to the class of work they are doing. A frame under average spinning conditions will require from .00725 of a H. P. to .0162 of a H. P. per spindle, or 137 spindles per H. P. to 61 spindles per H. P., according to the speed at which they are operated. In the first mentioned figures the speed is 7,000 revolutions per minute, and in the last mentioned figures it is 11,000 per minute.

To insure perfect lubrication and to reduce friction to the minimum the spindle bases are so arranged that the lower end of the spindles are immersed in a chamber filled with oil. Fig. 40 shows a sectional view of a spindle and its oil chamber. The oil is poured in through the upright arm of the base, which is fitted with a metal cover to prevent entrance of dirt, the oil flows into the space surrounding the lower end of the spindle, inside of the base and surrounding the spindle is the bolster, which is perforated with a few small holes, over the bolster is placed a piece of tubular wicking called "packing," through which the oil saturates and also prevents the entrance of dirt, the spindle rests on a hardened steel "step," and is supported in position by the inner surface of the bolster.

Oil for spindle lubrication must be especially suited for the purpose. It must be of a limpid and free-flowing nature and at the same time have sufficient body or viscosity to prevent wear between the bolster and the spindle. It should be of good cold test, free from any substance that will oxidize or thicken it, and should have a high evaporative test. It should be of 32 to 34 gravity B'.—about 140 to 160 viscosity, at 70 degrees, (Tagliabue), cold test of about 25

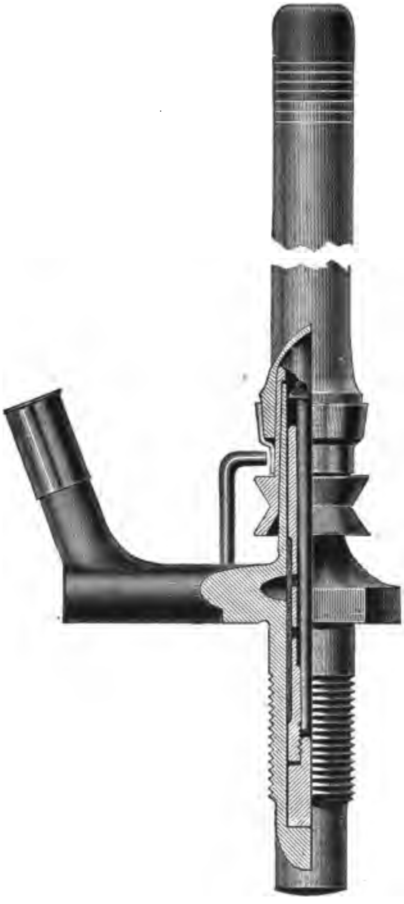

Fig. 40. Self-Oiling Spindle.

degrees and evaporation test of not to exceed 4 to 5 per cent. when heated for 12 hours at 150 degrees.

Any unnecessary amount of viscosity will have a retarding effect on the spindlles, and require an increased amount of power to operate them to the required speed. If the oil is of poor cold test it will have a tendency to congeal in cold weather and unless the rooms are at a high temperature it will have the same effect on the speed as in the case of a too viscid oil. If of low evaporative test the oil when heated by the ordinary friction heat will give off vapors which are inflammable, and will leave the remaining oil in the spindle base too viscid, thereby increasing the frictional load.

The spindle bases are usually oiled about every two weeks. A very little of a good quality of oil is required to maintain the proper height in the chamber, but if new, the spindles should be oiled oftener, and if on examination the oil is found to be discolored, indicating metallic wear, and of course excessive friction, the oil should be pumped out, all the parts cleaned and the bases filled with clean oil.

The spindles are operated by means of bands made of round twisted roving. These bands pass around the cylinder which is about five inches in diameter and extends the length of the frame, and around a small grooved pulley on the spindle, called a "whorl." The principal cause of spindle friction is due to the pull of these bands, and it is of the greatest importance that the bands be kept to the right degree of tightness. If too loose the bands will slip and the spindles will not run at their proper speed, while if too tight the frictional load will be increased, resulting in an increase in the power consumption and an increase in the temperature of the spindle bases.

The best results will be obtained when the bands have a tension on the whorl of about two pounds. The amount of tension can be determined by means of a small scale so arranged as to show the pull on each band when applied to it. The humidity or amount of moisture in the air will affect the tension of the bands very materially, as they are very sensitive to moisture. Any increase in the amount of moisture in the atmosphere will tend to tighten the bands, thus increasing the friction.

Mr.W. F. Parish, Jr., engineer for the Vacuum Oil Co., Boston, Mass., who has had a great deal of experience in making friction tests of textile fabric machinery, and is considered an authority in this work, states that "any reduction in horse-power reading of the frame due to the use of a more suitable lubricant will always show in a reduced temperature of the spindle bases; the lessened resistance on the spindle bases which is followed by a lower horse-power reading also shows through a lessened slippage of the bands, or, in other words, the spindle will revolve faster to the same speed of cylinder."

He also states that "the actual temperature of the spindle bases above the temperature of the room will run from 5 to 20 degrees. On a test recently made the oil in use showed an average temperature throughout the test of 20 degrees. A change of lubricant was made and the horse-power was reduced 14 per cent., with a reduction of 4 degrees in the temperature."

Mr. Parish states that "other tests have been made which have shown a reduction in frictional heat of almost one-half, the temperature being reduced from 10 to 18 degrees."

LUBRICATION OF SELF-OILING BEARINGS.

The advent of the electric dynamo and motor with its high rotative speed of journal brought about the development of the reservoir or self-oiling bearing, and from these it was simply a matter of mechanical adaptation to extend this economical and efficient appliance to engines and shafting.

While a small amount of good oil constantly applied to a bearing and journal in good condition will keep it from heating, yet in ordinary every-day service conditions are not always good and it has been found by experience that a lower coefficient of friction and cooler bearings will be obtained by the use of a self-oiling or flooded bearing.

Figure 41 shows a cut of a self-oiling bearing, and which requires very little explanation. As will be seen it consists of an ordinary babbitted bearing surrounded by a large oil chamber. Equi-distant from the ends are openings in the bearing through which travel metal rings which move by contact with the journal. The lower side dips into the oil in the reservoir and conveys it to the top of the bearing, where it is distributed along its length and flows between the wearing surfaces.

The oil in passing between the bearing and the journal will absorb whatever frictional heat there may have been generated, and drains back into the reservoir, where it gives up its heat in the large body of oil and becomes cooler. The body of oil in the reservoir is so great as compared with the quantity of oil on the journal at any one time that the dynamo can be run for a great length of time without the temperature rising much above that of the room; and part of that heat may be due to the heat generated in the adjacent armature and field coils.

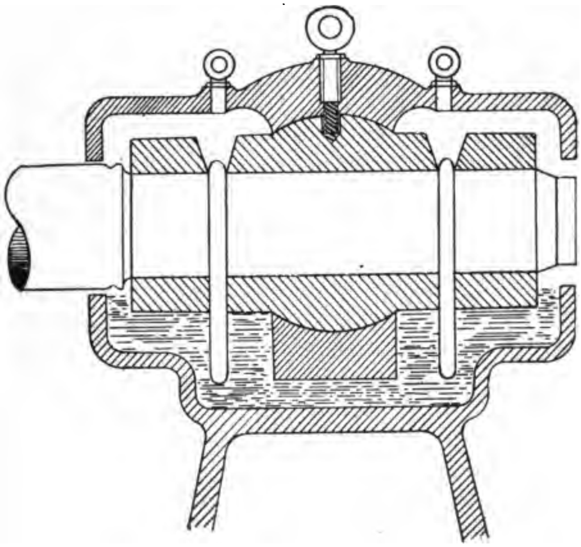

Fig. 41. Self-Oiling Bearing.

An oil suitable for self-oiling bearings must be of good quality and free flowing; it should have a gravity B'. of 27 to 29, a flash test of 375 to 425, and a viscosity of 160 to 200 (Tagliabue).

If the oil is of poor flash test the frictional heat will cause the more volatile properties to vaporize and leave the oil too viscid.

If the oil is too viscid it will not spread out quickly over the surfaces, and in starting up after standing for awhile, the oil having all drained back into the reservoir, intense friction may be created and heat generated before the oil has a chance to spread over the wearing surfaces. A dense viscid oil will also have a retarding influence on the speed of the journals, and tend to increase the friction load.

Dynamos and motors that are exposed to extreme cold weather should use oil of low cold test.

Some engineers make a practice of changing the oil in the reservoirs every few days or weeks, with a good oil this is not necessary. In fact, the author knows of an instance in which a street railway generator was running at a high rate of speed and under heavy duty for over three years without the oil being changed or an additional drop added, and there was no perceptible rise in the average temperature; and aside from being a little darker in color there was no apparent change in the oil. This, of course, was an exceptional case. Most bearings will leak a little, or otherwise have a slight wastage of oil, so as to require an occasional replenishing.

In order to always keep the oil in the reservoir clean it is a good plan to draw off a little of it occasionally through the drain cock just before starting up. After standing awhile whatever dirt the oil may contain will have settled to the bottom of the reservoir.

Dynamos and motors are usually so designed and constructed as to present very little difficulty in regard to the lubrication of their bearings and journals, which are usually of the self-oiling type, and if the oil chambers are kept filled with a suitable oil the temperature of the bearing will seldom be more than a few degrees higher than the temperature of the room.

If the temperature should be very much above the temperature of the room it will be advisable to ascertain the cause at once, as the old saying, "a stitch in time saves nine" is never more applicable than in the case of a heating bearing. A dynamo bearing may heat from any one of several causes.

The oil may not be suitable for the purpose, or it may have leaked out so as to be so low in the chamber that the rings or chains can not convey any oil to the journal surfaces; or the rings may have stuck and ceased to revolve. Cases have been known where the pins in the links of the oil-conveying chain have come out and allowed the chain to drop down into the chamber.

Excessive friction and heating is often caused by tight belts. Cases have been known in which the babbitt in one bearing was softer than in the other, and had wore down more, so as to tilt the shaft slightly, thus it did not have a full contact the whole length of the bearing; the concentration of the weight over a smaller area resulted in a higher temperature.

Another cause of heating in dynamos, especially when they have been in use for a number of years, is often due to the inequality of the magnetic attraction between the armature and the pole pieces. Owing to the gradual wear of the bearings the armature had dropped below the center of the fields and the increased magnetic pull downwards added to the weight of the shaft and armature, caused a decided increase in the friction.

Mr. J. C. Jenks mentioned an instance of heating of a dynamo which was traced to a stray eddy current, which took for its path the shaft and bearing, breaking through the insulation of the oil film on the bearing; the resistence to the current caused the heating.

The trouble was remedied by proper insulation.

OILING DEVICES, APPLIANCES, OIL FILTERS AND AUTOMATIC OILING SYSTEMS.

As the successful and continuous operation of machinery, and especially engines, depends upon the supply of lubricant to the wearing surfaces, no reasonable cost is too great for appliances that will insure the desired results, as a shut-down on account of a hot bearing or crank-pin, in a large manufacturing establishment or power plant, will result in a loss, if even for only an hour, that would more than pay for the equipment of the engine with suitable oiling appliances.

With small high-speed engines the best results and lowest per cent. of friction loss will be attained by the use of a crank-case enclosing the moving parts, and thus enabling them to be run in a continuous spray of oil, but with large engines this is not usually practicable, and resort must be made to sight-feed oil cups, continuous oiling systems, etc.

The oil cups should be well made and substantial, and be provided with needle point valves that will admit of close regulation; crank-pins can be lubricated best and most economically by means of "centre oilers" and cross-heads and eccentrics by means of "telescope oilers."

Figs. 42 and 43 show cuts of this type of oilers manufactured by the Wm. W. Nugent & Co., and their application to engines; with these appliances properly attached, every drop of oil that leaves the cups goes direct to the wearing surfaces, and as much or as little oil can be fed as desired, without fear of wastage.

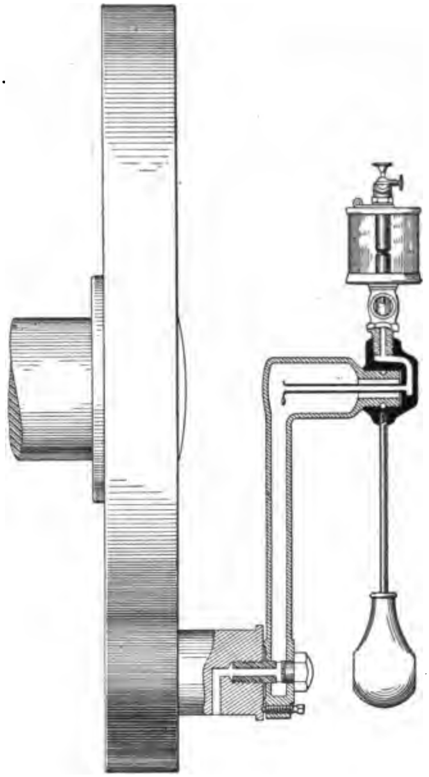

Fig. 42. Center Oiler.

ECONOMICAL OIL PUMP.

In a large manufacturing establishment where there are many machines in use the oil wastage due to careless on the part of the operatives is considerable.

As a general thing an employee when filling his oil can will allow it to overflow, then wipe the surplus oil off with a bunch of waste; and in a works where there are several hundred employees using oil, the amount of oil lost in this way will amount to a good many gallons in the course of a month.

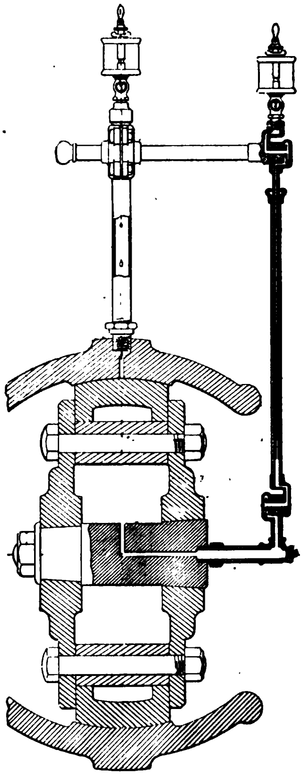

Fig. 43.

Fig. 44 shows a cut of an oil pump so arranged as to prevent loss of oil by overflowing of the cans. As will be seen, it consists of a pump attached to a pipe whose length can be regulated to suit the depth of the tank or barrel in which it is used.

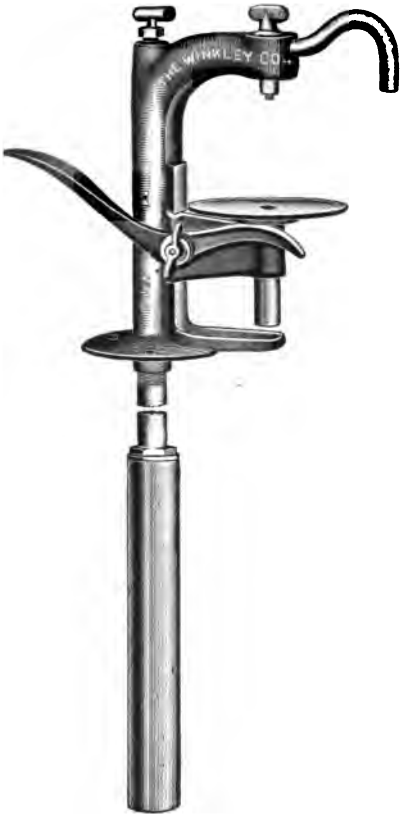
THE WINKLEY CO.

Fig. 44. Oil Can Filler.

To the curved neck of the pump is fitted a double tube, one inside the other, the inner tube projecting slightly below the outer tube.

The can to be filled is placed on the adjustable table, and by bearing down on the lever it is raised up against a leather collar which surrounds the discharge tube and forms a tight joint with the mouth of the can; while held in this position the can is filled by raising the pump handle the oil flows into the can through the central tube while the outer tube acts as a vent and syphon, any more oil than enough to fill the can is drawn up and returned to the tank, the syphon action established in the outer or overflow tube draws the oil in the can down to the end of the inner or filling tube, thus leaving room to insert the spout without overflowing, in this manner oil cans can be filled quickly and without loss of oil.

Every effort should be made to collect and filter or purify the oil after it has been used, in order that it may be cleansed of its impurities and used over again without danger to the machinery.

To accomplish this purpose filters of various kinds and operating on different principles have been invented by engineers and placed on the market.

While the object of all is the removal of the dirt from the oil and rendering it pure and clean, it has been accomplished by many ways and with different kinds of filtering materials.

Some makers of filters use cotton waste packed in perforated receptacles as a filtering medium; other filtering mediums commonly used are felt, canton flannel, Turkish toweling, wicking, sponges, sand, sawdust and charcoal.

One well known maker of filter uses no filtering medium whatever, depending for its operation upon the length of time that a given quantity of oil takes to pass from the inlet funnel to the outlet faucet; on the principle that the oil in the length of time that it takes to make this circuit, will part with its impurities by precipitation, the dirt settling on an inclined bottom where it can be easily drained off through faucets.

Another make of filter depends for its operation on the well-known principle of capillary attraction, the dirty oil being absorbed by wicking, the clean oil passing into a separate receptacle, leaving the dirt in the wick, which can be cleaned or renewed at slight cost.

Still another make of filter depends for its operation on hydraulic pressure. The water pressure coming under the body of oil in the main tank forces it through a thick layer of fibrous filtering material, into a smaller receptacle, whence it can be drawn off for use.

The author, in conjunction with Mr. W. A. Haller, formerly chief engineer of the First National Bank building, Pittsburg, and later with Mr. Thomas Kirk, formerly chief engineer of the Wheeling Electrical Co., at Wheeling, W. Va., has made some very satisfactory experiments in cleansing lubricating oil by centrifugal force, using an ordinary creamery separator, and if manufacturers of separators would make a separator especially designed for purifying oil it might meet with a ready sale.

But no matter what type of filter is used it will require some care and attention. Cleanliness is the price of pure oil, and the tanks should be emptied and cleaned frequently, and the filtering material should be washed or renewed.

Many filters are equipped with steam pipes so that the oil may be heated and its gravity and viscosity lowered in order that the impurities may precipitate more freely.

While the heating of oil to a moderately high temperature, say to 125 or 150 degrees, will not affect the quality of the oil, it should not be boiled by high-pressure steam. With a pure petroleum oil its condition may not be changed materially, but if any animal fats be present in the oil as may be the case where cylinder oil has gotten in with the engine oil, the animal oil and water will emulsify under the high temperature and render the whole mass milky and opaque, instead of being clear and transparent.

In filtering oil it is a good plan to allow it to stand in a covered tank or in pails in a warm place for several days before putting it into the filter. This will allow a large percentage of the heavier dirt to precipitate and the cleaner oil at the top can be poured off or dipped out into the filter, thus allowing the filter to be used for a longer time before cleaning.

In cases where the best results in lubrication at the least cost for oil and attendance is desired it will be found profitable to equip the engines with an automatic oiling system; this, if properly attached, and the engines fitted with ample oil shields and drip-pans, will enable the engineer to keep the bearings continually flooded with oil, reduce the cost of attendance, insure against liability to hot bearings and permit of the oil being used over and over with slight wastage.

Figure 45 shows a view of a large engine equipped with an automatic oiling system installed by the Pittsburg Gauge and Supply

Co., the operation of which is as follows: The oil flows by gravity from an elevated reservoir through a system of piping to the various bearings, the flow of oil being regulated by one or more needle point valves at each bearing; the oil, after it leaves the bearing, flows to a filter located below the engine; here the oil is filtered and freed of its impurities by passing first through water and thence through layers of especially prepared filtering cloths, which catches and retains all impurities, and allows the clean

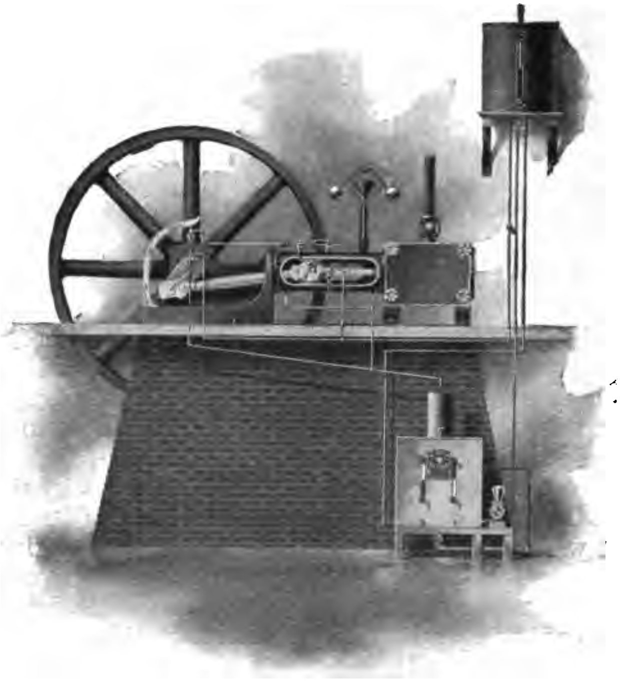

Fig. 45. Automatic Oiling System.

oil to settle in the storage chamber; from thence it is pumped to the overhead tank to be used again; the pump is regulated by an automatic device so as to maintain a constant height in the overhead tank, thus insuring a constant gravity pressure on the oil supply valves.

LUBRICATION OF STEEL WORKS, ROLLING MILL AND BLAST FURNACE MACHINERY.

The lubrication of steel works and rolling-mill machinery as far as the ordinary shafting and auxiliary machinery is concerned, does not present any serious difficulties to the engineer.

As it usually runs at a moderate rate of speed and the load on the bearings is seldom excessive, any medium bodied oil will answer very well.

But there is a great deal of machinery in a rolling mill that requires special lubricants adapted to the requirements.

The rolls which are used to roll out steel and iron bars, sheets, boiler plate and structural shapes are provided with journals or "necks," as they are called, which are nearly as large in diameter as the rolls themselves.

These rolls are placed in frames or "housings," one roll on top of the other, the lower roll rests in bearings at the bottom of the housing, and on the necks of the top roll are placed bearings on top of which rests the ends of the roll screws, the position of which determines the thickness of the material that is being rolled.

These screws when tightened down hard with a piece of steel between the rolls, create a tremendous pressure on the bearings and necks, and the necessity for perfect lubrication is therefore of the greatest importance.

Rolls used for rolling tin plate and sheet steel are called "hot rolls"; as owing to the nature of the work no water can be used on the necks and they and their bearings run at a very high temperature.

The lubricant to use under these conditions must be a grease of high melting point and very adhesive, such greases are usually composed of heavy petroleum residuum and animal greases, combined with finely powdered talc, soapstone, lime or graphite. Hot neck grease is of such a dense nature that it is necessary to melt it over a fire before it can be used, and it is applied while hot to the roll necks with a swab.

The hot neck grease after being used should be gathered up and re-melted, allowing the dirt to settle in the bottom of the melting pan, and run off into cooling pans; when cooled it can be cut up into cakes and used over again. It may be necessary when re-melting to thin it down by adding more residuum oil.

Cold rolls are those that are used for rolling out rods, bars, rails, structural shapes, etc., and the housings are fitted with pipes so that streams of water can be kept running over the roll necks so as to prevent them from becoming over-heated.

The greases suitable for use on cold rolls are composed largely of tallow or suet, either used alone or combined with petroleum greases, in which case they are called "tallow compounds," and can be made in varying degrees of hardness.

Cold neck grease is usually applied by packing it on the neck surface. Sometimes it is placed in bags made of burlap and packed tight against the necks, the grease gradually melts out of the bags and adheres to the necks.

The teeth of the large gears and pinions in a mill should be kept well lubricated to prevent their wearing, and also to deaden the noise. This can be accomplished best by coating them with some dense plastic compound that will form a slippery enamel-like coating that will not drip or flake off.

This should be put on when in a melted state while the gears are turning slowly, so that it will spread out evenly without spattering before it hardens.

Small quick-running gear wheels should be lubricated with some soft petroleum grease applied with a brush.

Bearings that are in close proximity to furnaces, soaking pits and hot billets and ingots can be lubricated best by the use of a graphite grease of high melting point.

Table-roll journals, table engines, electric cranes and other machinery adjacent to the rolls should be lubricated with medium heavy oil, and all oil holes, bearings, etc., should be kept covered to prevent entrance of dust and mill scale, as rolling mill machinery is not always well protected from the weather it is a good plan to use a heavy viscid oil that will "stay on" in hot weather, and a thinner oil of low cold test which will not congeal in the cups during cold weather.

Blast furnace blowing engines are usually placed in well protected engine rooms. They run at a moderate rate of speed, the journal pressures are not excessive, and a medium heavy petroleum oil will give good results.

The air cylinders or "blowing tubs," as they are sometimes called, are easily lubricated with a small quantity of ordinary machinery oil; with some of the old types of air cylinders fitted with wooden piston rings, a mixture of water and flake graphite give excellent results.

For lubricating the bearings and wheel spindles of pig-iron casting machines and hot-slag conveyors, owing to their close proximity to the hot metal the best and most economical results will be obtained by the use of a soft graphite grease of high melting point.

LUBRICATION OF HYDRAULIC ELEVATORS, PUMP PLUNGERS, &c.

The efficiency of an elevator system will depend very materially upon the attention paid to the lubrication of the rubbing surfaces.

Various means are taken by engineers to lubricate the internal wearing surfaces, some occasionally pump cylinder oil into the water plungers below the pistons when they are at the bottom of their stroke, when the pistons travel upward the oil will follow and in doing so will spread out over the cylinder surface.

Some drain the condensation from the engine exhaust into the elevator tanks, the cylinder oil in the water will emulsify with it and serve to lubricate the internal parts.

Other engineers accomplish the same purpose by the use of soap or soap powder. A pound or so of soap or soap powder dissolved in water and poured into the tanks occasionally will afford very good lubrication.

The wire cables are subject to corrosion from moisture and from abrasion, due to the friction of the strands on each other while passing over the sheaves, and for this reason they should be kept well lubricated.

For this work an oil is preferable to grease, as oil will penetrate between the strands and prevent wear, while a grease or composition cable coating will remain on the outside and being of a sticky nature the dust in the elevator shaft will adhere to it and in time it will get dry and hard and flake off.

A very ingenious yet simple device for lubricating elevator cables shown in Fig. 46, is the invention of Mr. M. H. Halloran, a well known Pittsburg engineer. As will be seen the device consists of a sheet steel pan or receptacle atreached below the traveling sheave.

Inside the pan is a wooden roller so arranged by means of a pair of springs that its lower edge dips into the oil, while the upper edge of the roller comes in contact with the cable as it travels back and forth, thus conveying a thin film of oil onto the outer strands, which soon penetrates between them and keeps them all well coated with oil and prevents wear of the strands.

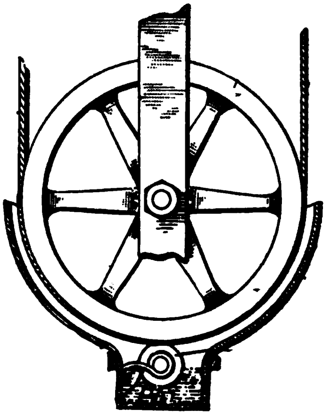

Fig. 46. Oiler for Elevator Cables.

Other parts of an hydraulic elevator that need attention are the elevator rods. They travel up and down through the cylinder and are subject to wear from friction and corrosion; it is necessary, therefore, that attention be given to their lubrication.

A very efficient device for this purpose is shown in Fig. 47. This combination packing-box and lubricator, which is the invention of Messrs. A. G. Allen and S. B. Forse, consists of a brass cup so arranged as to have space for two compartments, each of which contain several rings of soft packing, and another compartment between them that can be kept filled with a lubricant.

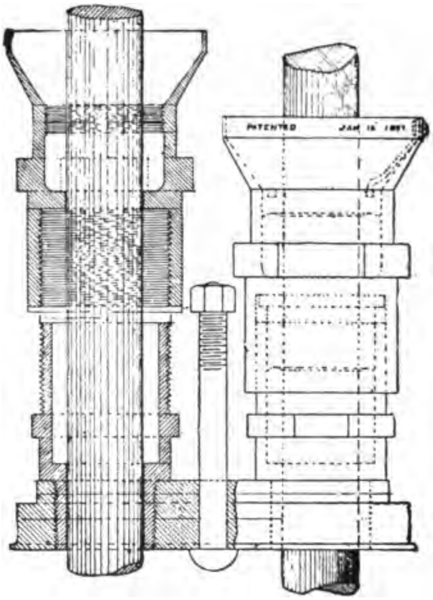

Fig. 47. Elevator Rod Lubricator.

It is usually the practice to pack the water ends of high duty plunger pumps with fibrous packing of some kind, usually of hemp or flax.

This packing is generally plaited up with some plastic lubricant, such as tallow, etc., but many engineers claim that they obtain the best results by soaking the packing in hot cylinder oil or in a mixture of oil and graphite before placing it in the stuffing box.

It is customary with some engineers to apply soft grease to the surfaces of the plungers occasionally by means of a brush, and while grease is in some respects a very efficient lubricant for this purpose, yet on large engines grease has been found to be very wasteful of power.

In this connection mention might be made of some tests made by Messrs. H. E. Fernald, Harry Stevenson and the author in order to determine the percentage of friction loss by the use of grease on the water plungers of large pumping engines.

The first test was made on a vertical compound pumping engine running under a constant load and at 20 revolutions per minute, and having four plungers, two being 31½ inches and two 22 inches in diameter, all having a uniform stroke of 64 inches.

The plungers were packed with square hemp packing which had been well soaked in oil. Two sets of indicator cards were taken, about 20 minutes apart, which showed the engine to be developing 762.67 horse power. A quantity of soft grease was applied to the plungers and time given for it to get well worked into the packing (about an hour), and two more sets of cards were taken, about 20 minutes apart. These last sets of cards showed the engine to be developing 835.17 horse power, showing an increase of 72.5 horse power, or over 10 per cent. in the friction load.

Another test was made by Mr. Harry Stevenson and the author on a large Nordberg quadruple expansion engine at the pumping station of the Pennsylvania Water Co., of which Mr. Stevenson is the chief engineer.

The four plungers of this engine are 14 inches in diameter and have a stroke of 42 inches. The first cards taken before the grease was applied showed the engine to be developing 742.10 horse power and after the grease was applied 793.10 horse power making an increase of 51 horse power.

Figuring on a coal consumption of two pounds of coal per horse power per hour, the increase in the first mentioned test would amount to 145 pounds of coal per hour, or 3,480 pounds per day of 24 hours.

LUBRICATION OF FLOUR MILL MACHINERY.

The machinery in a flour mill that requires the most careful attention to the lubrication is the journals of the rolls used in grinding the flour.

Roll journals run under a pressure of from 2,000 to 5,000 pounds per journal, and at a speed of about 500 revolutions per minute, and a good quality of free-flowing oil of 28 to 30 gravity B′., 375 to 425 flash test, 160 to 175 viscosity (Tagliabue's). For cold weather an oil of low cold test that will not congeal and retard the speed of the machinery should be used.

Reciprocating machines are usually run at a speed of from 550 to 600 revolutions per minute, and as they are counterbalanced and comparatively easy of lubrication, a medium bodied oil will give best results.

Where power is cheap a good grade of soft grease may be used with very satisfactory results, but as the tendency of grease is to cause an increase in the frictional load it should not be used where the cost of power is an important factor in the operation of the mill.

Mr. George C. Hinkley, manager of the Daisy Roller Mills, Milwaukee, Wis., and one of the best authorities on flour mill work in the country, informs the author that the increased consumption of power in a modern mill, due to the use of a good quality of soft grease will be about 7 per cent., as compared with oil, and will increase rapidly with the hardness of the grease.

LUBRICATION OF BELTS.

Owing to the fact that friction occurs between the fibres of a leather belt it is necessary that they be kept lubricated to prevent them wearing and cutting each other and thus causing the belt to become brittle.

The application of a suitable preservative may properly be classed as lubrication, as any substance that is put on a belt that does not penetrate below the surface and lubricate the fibres of the leather is only an injury to the belt.

As has been aptly stated in a valuable little book entitled New Knowledge of Belt Management:* "By giving the fibres of a belt a surrounding cushion of lubricant," "each particular fibre is held in a sheath of lubricant."

Before applying a preservative the surface of the belt should be thoroughly cleaned of dirt, the preservative should be applied hot to both the inner and outer surfaces by means of a brush or by pouring it on in a thin stream from a coffee or tea-pot while the belt is traveling slowly.

A seeming anomaly in connection with the treatment of belting is, that while a lubricant is used to prevent friction, yet a properly treated belt will show least friction between the fibres of the leather and greatest friction between the belt and the pulley surface.

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*Published and issued by the Cling-Surface Manufacturing Company, Buffalo, N. Y.

LUBRICATION OF ENCLOSED CRANK CASE STEAM ENGINES.

The general use of high-speed engines and the importance of their perfect lubrication has brought about the development of the enclosed crank-case type of engines, in which the cranks revolve in a bath of oil conveying it continuously and in large quantities to the wearing surfaces.

The "Ideal" and "Standard" types of engines manufactured by the Harrisburg Foundry and Machine Works are very good examples of horizontal engines, and the "Westinghouse" of the vertical type.

In the first-mentioned class, as will be seen by reference to Figs. 48 and 49, the crank discs are covered by a sheet steel hood or shield which fits tightly on the engine frame.

The oil, which must be of pure petroleum and of first class quality, should be poured into the reservoir in the frame below the crank-disc until the lower edge of the disc is immersed in the oil to the depth of one-half to three-fourths of an inch.

When the engine is started the crank-disc throws the oil back over the guides and crossheads so that when running at full speed they are immersed in a spray of oil. The crank also throws a volume of oil against the shield, to the inner surface of which is riveted a trough which retains part of the oil from whence it flows through pipes to the shaft bearings. From the bearings the oil runs into a groove in the outside face of the crank disc, from whence it flows by centrifugal force through oil holes to the crank-pin. Thence the oil is thrown out against the shield and drains back into the reservoir.

Engines of this type often show a friction loss of less than 2 per cent.

In the lubrication of vertical steam engines such as the Westinghouse, conditions are found which are radically different from those met with in the lubrication of ordinary horizontal engines.

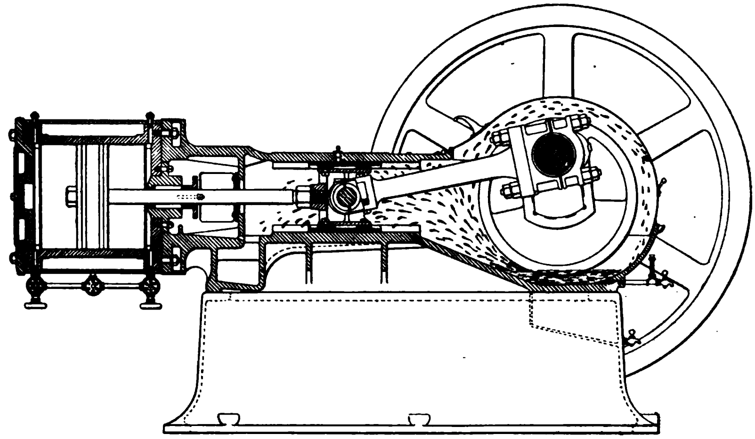

Fig. 48. Enclosed Crank Case Engine. Side View.

In this type of engine, as will be seen by Fig. 48, the shaft and cranks are enclosed in a crank-case containing oil and water. The rapidly revolving cranks throw the water and oil with such force, and in such quantities as to maintain a perfect flood of oil on the journals, pins and cylinder walls, as the oil is drawn up by the action of the pistons.

In the Westinghouse steam engine it is necessary to use water in connection with the oil. Being a vertical engine the water due to condensation is continually working down past the piston rings and dripping into the crank case.

At the proper height above the bottom of the crank-case an overflow or syphon pipe is provided so that the excess of water can pass out, as the oil and water are mixed and churned together by the motion of the cranks a large proportion of oil will pass out through the overflow pipe with the water.

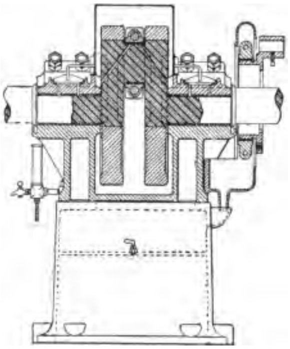

Fig. 49. Enclosed Crank Case Engine. End View.

The oil is separated from the water and retained in a separator provided for this purpose, which consists of a circular iron box or tank about 18 or 20 inches in diameter and 12 or 14 inches in height (See Fig. 51). This separator is divided into four equal compartments by partitions at right angles to each other. The oil and water flowing from the crank-case through the overflow pipe enters the first compartment when full, the water flows through a passage into the next compartment, leaving part of the oil floating on the surface of the water in the first compartment. Any oil that is not retained in the first compartment is carried into the second compartment where it is given another chance to separate, and so on through the third and fourth compartments; and by the time the oil and water have passed through all four compartments the water has become freed from the oil and flows thence to the sewer or drain.

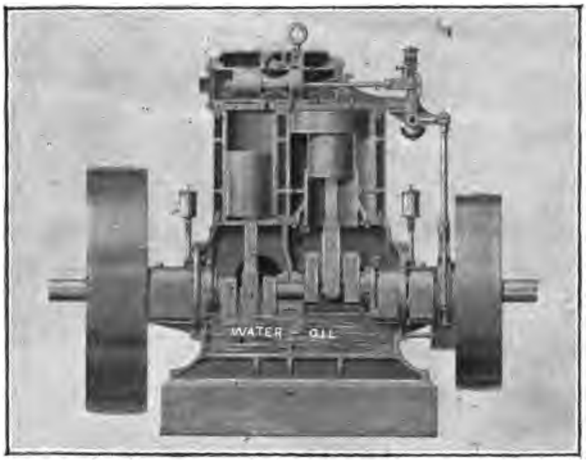

Fig. 50. Westinghouse Steam Engine.

The oil remaining on the surface of the water in the compartments should be dipped out occasionally and poured back into the crank-case.

In some of the larger plants, where a number of Westinghouse engines are in use, instead of the usual separator tank furnished with the engines, a system of piping from the overflow of each engine conveys the oil and water to two or more large separating tanks in the basement, where, after separation takes place, the oil is pumped up into the engine room to be used over again.

To a great extent the successful operation of a Westinghouse engine depends on the attention which is paid to its lubrication. Many engines of this type have been condemned as being too expensive on account of always needing repairs, etc., while the whole trouble was that the lubrication had not been properly attended to; in other plants in which there was a number of large Westinghouse engines in constant use day and night, their lubrication being attended to in a systematic manner, no trouble is experienced and no repairs are needed.

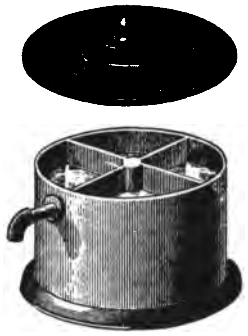

Fig. 51. Oil Separator for Westinghouse Steam Engine.

In preparing to start a Westinghouse engine the first thing to be looked to is to see that the crank-case is perfectly clean and free from dirt and grit, then fill it with clean water nearly up to the overflow outlet, then pour in enough oil to form a layer on the surface of the water about one-quarter to one-half inch deep. The oil that is suitable for this purpose should be of pure petroleum, dense enough so that it will not become too thin when mixed with the water which usually attains a temperature of about 200 degrees, though it must be of such a nature that it will mix freely with the water in the crank-case and separate quickly in the separator, allowing the water to pass out clear and free from oil.

After the engine is started and the oil and water commence to pass out through the overflow, more oil should be added at intervals of three or four hours, thus maintaining constantly the same proportion of oil to water.

In some cases where the piston rings fit the cylinders very snugly and the water does not leak by them very freely, it will not be necessary to replenish the oil so often.

A little watchfulness on the part of the engineer in charge will enable him to know how much and how frequently the oil must be replenished in order to maintain proper lubrication.

If the piston rings become worn or slack considerable wasteage of oil is caused by the oil working up on top of the piston and being carried out by the exhaust steam into the exhaust pipe. Some of this oil may be caught again by placing a suitable drain pipe in the exhaust pipe so that the oil will drain back into a barrel or tank provided for the purpose.

GREASE.

Grease as a lubricant has its special uses and also its limitations; for use on engines and general machinery it will not reduce friction to the same degree that oil will, but there are many places where oil would be impracticable.

Greases are solidified oils and are known as plastic lubricants. Mr. Charles E. Carpenter, of Philadelphia, a recognized authority on lubricants, has very aptly described the difference between a fluid and a plastic lubricant "as being due to their molecular construction, in an oil the molecules are of a flexible spherical shape which revolve on and against each other, while in a grease they are irregular in shape, with no tendency to free movement."

Most greases have as their base petroleum oil of low lubricating power, combined with some animal oil and the whole solidified by the admixture of lime water, making a plastic compound which varies in its lubricating value according to its proportions and quality of the component parts.

While greases have certain advantages in the way of cleanliness, ease of application, etc., yet on general mill and factory machinery the use of grease instead of oil will tend to increase the friction load.

The author knows of an instance in a flour mill in Maryland in which, when using grease, it was impossible to keep up steam and run at full speed the first hour or so in the morning. The weather being cold the grease (which had melted by frictional heat on the previous day) had congealed during the night. After running an hour or so the frictional heat melted the grease and allowed the machinery to be run at full speed the rest of the day.

A change to oil resulted in quite a saving in fuel and enabled the mill to be run at full speed at all times.

Some years ago the author made some tests in a paper mill in Pennsylvania to determine the difference between oil and grease on a stack of super-calender rolls. Grease had always been used and the impression prevailed in this mill that nothing else could be used. A preliminary test on one bearing showed a reduction of temperature in 12 hours of 41 degrees, and a test made on the whole machine showed an average decrease in temperature of 29 degrees in 12 hours.

The temperature of the room was the same in both tests, this machine was in constant use 142 hours each week.

BEARINGS AND JOURNALS.

Bearings are the surfaces of contact between the frame of a machine and the moving parts, and support and guide them, and the revolving and rotating parts are known as journals and pins.

It is in the bearings and journals of a machine that the greatest amount of friction is generated, and in order to keep the friction down to as low a point as possible the bearings and journals must be of proper proportion and made of suitable materials, thus to sustain the pressure and strains, and they must be so arranged as to admit of a free flow of lubricant between the surfaces.

Bearings are usually composed of different metals, which combined will form a tough, ductile and homogeneous composition which will sustain the heavy pressures, shocks and strains incident to the operation of engines and machinery. These materials are known as brass, phosphor bronze, gun metal, white brass and babbitt metal, and are composed of different proportions of copper, zinc, tin, lead, antimony, bismuth and phosphide of iron or manganese.

The essential requirements of a good bearing metal are first, that it shall have high anti-frictional properties, so as to withstand heavy pressures at high speeds without heating. Second, that it shall be hard enough so as to not squeeze out of place under heavy loads or crack or break under severe shocks and blows. Third, that it shall be of such a nature as to be easily renewed when worn out, and finally that it can be re-melted and used again.

There are two general classes of these alloys, those which contain a large per cent. of copper and a small amount of the softer metals. These are known as hard metals, or brass or bronze; and those which contain a large proportion of tin or lead and a small per cent. of copper, are known as soft metals:—babbitt metal, anti-friction metal, white metal, etc.

In some instances and under certain conditions it has been found that a good close-grained cast-iron makes an excellent bearing metal. Being of a granular nature it has the property of retaining the lubricant in place, even when highly polished and under great pressure; with a low coefficient of friction, but is too brittle to withstand severe shocks.

The special advantages of the soft metals over the hard metals are their cheapness and ease of renewal, and while in the testing machine they may not show as low a coefficient of friction as the hardest metals, yet they have the property of adapting themselves more readily to the irregularities of the journal surfaces with which they are in contact, and run at a lower temperature.

They do not usually have sufficient strength in themselves to sustain the weights and shocks of the heavy rotating parts of engines and machinery. For this reason they are generally used as a liner or layer which is run, in a melted state, into a shell which is composed of tougher and harder metals, usually of bronze or brass, although in recent years many engine builders are using a close grained cast or malleable iron shell or box to contain the soft metal.

Tin imparts toughness and hardness to an alloy and has the property of giving other metals a fine grain. Lead has great anti-frictional value, and gives to the wearing surfaces a soft, smooth, yielding nature, but of itself will not sustain heavy pressures. Antimony tends to make the alloy hard and brittle but coarser in grain. Zinc tends to increase the solidity and combine closer the other alloys of copper, tin and lead; copper gives strength and toughness to the other parts, and bismuth increases the fluidity of the other metals when melted.

Mr. Gulliam H. Clamer, second vice president and chemist for the Ajax Metal Co., of Philadelphia, a recognized authority on the composition of bearing metals, states, in a paper presented at a meeting of the Mining and Metallurgical section of the Franklin Institute, May 11, 1898, that "of all the metals, lead is by far the first in anti-frictional qualities, and if to the strength of copper and tin there is added a suitable proportion of lead, thoroughly and evenly distributed throughout the mass, the bearings as they wear are constantly in contact with soft anti-frictional particles of the lead which are backed by the harder particles of the copper and tin, but, if in such an alloy the lead is not homogeneously distributed both the wearing and the anti-friction qualities are affected."

Mr. Clamer also states "That a good babbitt metal should have as fine a grain as possible in connection with the greatest toughness and hardness obtainable," and that "The question of obtaining a fine grained structure depends greatly on the method of manufacture; temperature of pouring playing an important part."

The following table shows the composition and proportions of several kinds of soft metals which have been found to be very successful.

	Tin.	Lead.	Antimony.	Copper.	Zinc.
No. 1 metal	10.00	70.00	20.00	.....	.....
No. 2 metal	68.00	00.50	.....	1.00	31.50
No. 3 metal	96.00	.....	8.00	4.00	....

The ideal bearing metal will be attained when it combines in the greatest degree the soft, yielding property of lead with the toughness and hardness of copper, but owing to the great difference in specific gravity between lead and other metals, (see table on page 193) it has been a difficult matter to obtain a homogenous mixture in an alloy that contains more than a very small per cent. of lead, the lead being the heavier goes to the bottom, and the lighter metals remain on top when melted or when being poured, but after much study and countless experiments the Ajax Metal Co. have by a special process been able to obtain an alloy which contains a large per cent. of lead combined with the copper, and a very small per cent. of tin, which they call Ajax Plastic Bronze.

By this process this large per cent. of lead is combined with the copper without the slightest trace of segregation, and forms a bearing surface which resists wear and shows a very low coefficient of friction, its plastic nature allowing it to conform readily to the irregularities of the journal surface without heating.

Dr. Dudley, chemist for the Pennsylvania Railroad Co., states in a report on Bearing Metals, "That the loss of metal by wear, under exactly same conditions, diminishes with increase of lead," and "That loss of metal by wear, under exactly same conditions, diminishes with diminution of tin."

While the soft babbitt metals are used to a very great extent, there are some classes of work, especially in rolling mill and railroad work, where only the hardest and toughest bearing metals can be used; in rolling mills, and especially in sheet mills, where the rolls and the journals have a very high temperature, due not only to the close proximity of the red hot sheets, but also to the extreme pressure on the bearings. None but the hardest metals will stand the strains and temperature, ordinary babbitt or other white metal would soon be melted out by the heat. Where the heat is not too great, the brasses are sometimes provided with cavities or recesses into which the soft anti-friction metal is poured, the soft metal takes the greatest part of the wear, while the brass outer shell imparts strength.

In railroad work the brasses are often given a thin layer or lining of pure lead. As the journal surface is always more or less uneven, especially after having been run for awhile, the lead, under the weight of the car conforms easily to the inequalities of the journal surface, and at once forms a good bearing surface, while the brass to which the lead is attached prevents it from squeezing out.

Some railroads use brasses with a strip of soft metal in the crown of the brass where there is the greatest amount of wear.

These harder alloys are composed usually of the same metals as the softer alloys, except that the proportions of their component parts are different and consist principally of a greater proportion of copper and a lesser proportion of the softer metals.

These alloys are sometimes still further increased in strength by the addition of small quantities of ferro-manganese or phosphorus, in the first case the alloy is known as manganese bronze, while in the second case it is called phosphor bronze.

Where these hard metals are used in direct contact with the journal surface, and especially in engine work, great care should be taken that the wearing surfaces are very carefully fitted by filing and scraping. When the brass or bronze shell is to be filled with babbitt metal, in order to make a good job, the surface of the brass should be first cleaned of all dirt and oil by washing in gasoline or alcohol, then in the inner surfaces coated with solder by means of an ordinary soldering iron, this will cause the babbitt metal to adhere to the brass, many engineers and mechanics do not always take the time and trouble to do this, but when good results are desired it will pay.

In large manufacturing establishments where great quantities of bearing metals are used, it is sometimes customary to compound their own metals, but as a general thing if one is not an expert it will be found more economical in the end, and will give better results to use metals made by responsible firms who make a specialty of this work and have that thorough understanding of the business which guarantees the quality of their goods.

In babbitting bearings so many special conditions prevail that it is impossible to give a general rule to apply in all cases.

As a general example—in babbitting the bearings of a large engine shaft, if the metal is in cast-iron shells, as is usually the case, remove the shells from the engine frame and chip or melt out the old babbitt metal and burn off all the oil and dirt, being careful not to over-heat and warp the shells, then tin the inner surfaces of the shells, if a mandrel a little smaller than the journal is available, use that instead of babbitting in place on the engine.

Have the mandrel and shells well warmed, about as hot as they can be handled, coat the surface of the mandrel with chalk or carbon from the flame of a smoky lamp, or with a thin layer of graphite and oil, and stand it on end on a level board or metal plate, assemble the shells around the mandrel and at the proper distance, so as to give the required thickness of babbitt metal, securing the shells in place by strips of wood, and make a ring of clay or putty around the mandrel on top of the shells so as to retain the melted metal and prevent it from running over.

If no mandrel is available place the shells in position in the engine frame and level the shaft and see that it is exactly in line and square with the center of the cylinder, warm the surface of the journal with an electrician's gasoline torch or other convenient means and coat it as above.

Place the shells in their proper position and at the required distance from the journal to give the desired thickness of metal, if there is no collar on the shaft at the end of the bearing opposite the crank, provide a collar by sawing a hole in a board the size of the shaft, split the board and place the two parts in position around the shaft and close against the bearing, fasten them in place, first chalking the inner side where the hot metal will come in contact with it, this will prevent the metal from burning the wood and running out.

If the shaft is only 6 or 8 inches in diameter a ring of stiff clay or putty will answer the same purpose, but with large bearings the weight and pressure of the melted metal is apt to force the putty away, and a wooden collar is always preferable.

Have at least two holes in the top shell of at least ¾ of an inch in diameter, so that a good sized stream of metal can be pored in, make a ring of clay or putty around the holes an inch or so high, do not put the bearing cap on but secure the shells from lifting or spreading by strips or blocks of wood.

In preparing the metal, melt it slowly in a clean ladle and stir thoroughly, heat the metal enough to cause it to flow freely, being careful not to heat it too hot or too fast, as this will tend to volatalize the softer metals in the alloy, it is usually a safe rule only to heat the metal enough to brown the surface of a pine stick when dipped in it. When melted cover the surface of the metal with powdered charcoal to prevent it from oxidizing and making rough spots in the bearing when pouring the charcoal can be kept from running in with the metal by means of a flat stick or piece of iron.

When the metal is melted pour it slowly and steadily, so as to allow the air to escape and the metal to flow into every part of the shells. After the metal becomes cool and hardened, remove the shells and trim off the rough edges with a chisel and file; pene the surfaces well with the pene of a hand hammer to spread the metal out against the shells, and place in a lathe and bore out to the required diameter. If it is not practicable to bore them, the surface of the babbitt should be filed and scraped and fitted so as to have a perfect bearing on the journal, not forgetting to first drill the oil holes in the top shell and cut an oil groove along the crown from one hole to another, and also an oil groove along the bottom of the lower shell, and chamfer off the upper edges of the quarter-boxes so as to allow the oil to flow down freely.

Table XI. on page 193 gives the properties of metals most generally used in making anti-friction alloys, and table XII. on page 194 gives the composition of a number of different kinds of anti-friction metals.

TABLE XI.

PROPERTIES OF DIFFERENT BEARING METALS AND ALLOYS.

	Weight per cubic inch	Weight per cubic foot	*Specific gravity	Melting point (about)
	Lb.	*Lbs.*		*Fhr.*
Lead	.410	708.48	11.36	620
Tin	.263	454.46	7.27	443
Zinc	.254	438.91	7.10	770
Copper	.310	535.68	8.57	2050
Bismuth	.355	613.44	9.81	500
Cast Iron	.257	444.09	7.10	2010
Wrought Iron	.280	483.84	7.72	2900
Steel	.285	492.98	7.87	2550
Aluminum	.096	165.88	2.65	1300
Brass	.290	501.12	8.01	1650
Antimony	.241	416.44	6.66	1150
Phosphor bronze	.310	535.68	8.57	1900

*Specific gravity taken with water weighing 62.5 pounds per cubic foot.

Prof. Durand, in his work on "Practical Marine Engineering," gives the following table of bearing metals and their composition in parts of 100:

TABLE XII.

COMPOSITION OF DIFFERENT BEARING METALS IN PARTS OF 100.

	Copper.	Tin.	Lead.	Zinc.	Antimony.	Aluminum.	Iron.
Admiralty Bronze	87.00	8.00	....	5.	....	....	....
Aluminum Brass	63.00	....	....	34.	....	3.	....
" Bronze	89 to 98	....	....	....	....	11 to 2	....
Anti-Friction (A)	78.75	....	....	1.	19.6	....	.65
" (B)	1.60	98.13	....	....	....	....	a trace
" (C)	3.80	78.4	6.0	....	11.8	....	....
Babbitt Metal	1.80	89.3	....	....	8.9	....	....
" "	3.70	88.9	....	....	7.4	....	....
Yellow Brass	65.30	....	2.0	32.7	....	....	....
Manganese Bronze	88.64	8.7	.3	1.57	....	....	.72
Gun Metal	89.	8.25	....	2.75	....	....	....
Navy Journal Boxes	82.80	13.80	....	3.4	....	....	....
White Metal	....	....	88.0	....	12.	....	....

It will be noticed that the hard brasses and bronzes are composed largely of copper with small quantities of the softer metals, while the babbitt and other soft metals have a large percentage of tin or lead and a small percentage of copper.

HOT BEARINGS AND THEIR TREATMENT.

Every precaution possible should be taken to avoid hot bearings.

A bearing may heat from any one of several causes. The engine or shaft may be "out of line," the wearing parts may not be of proper proportion for the speed or pressures, or the wearing surfaces may not be made of suitable material; it may heat from being too tight, or the lubricant may not be suitable; the oil cups may have stopped up or ran empty, thus leaving the surfaces dry.

Heating may also occur owing to lack of sufficient compression of the steam in the cylinder at the end of the stroke.

An engineer should familiarize himself with the running temperature of his engines and machinery by frequent feeling of the bearings, or by the use of the thermometer, and after taking up lost motion he should watch carefully for any rise in temperature.

The first thing to do on finding a journal or crank pin heating is to loosen up the bearings or brasses, and apply oil freely till it cools off; after that take up the lost motion again very carefully, a little at a time.

If the metal becomes hot enough to burn the back of the hand when touched, (150 degrees or over) cylinder oil should be used, it having a higher fire test than engine oil. It will maintain its body or viscosity in contact with the hot surface, absorb the heat and carry it off, where the engine oil would burn.

Always avoid the use of water if possible. It does not lubricate, but merely absorbs the heat, while oil will not only absorb heat but lubricate also; but if if an engine must be kept running at all hazzards and the heating is excessive, a small stream of water at the ends of the bearing or on the collar of a crank pin, may enable it to run till such time as repairs can be made.

Where water is used directly on the wearing surfaces it should be used in connection with an animal oil, such as lard oil, or a mixture of lard oil and petroleum oil. Animal oil will adhere better to wet metallic surfaces than petroleum oil alone.

After a journal or pin has been overheated sufficient to cause the oil to burn, it will be about impossible to run it again successfully without refitting of the bearings or brasses.

If of babbitt metal the chances are that the surfaces of the metal have been melted, and that the oil holes and grooves have been filled up. If very badly melted they will have to be re-babbitted; but if the surface has been merely "pulled" it can be put in good condition again by the careful use of the chisel, file and scraper.

If heating has occurred to solid brass or bronze bearings, the chances are that they will have been warped by the heat to such a degree that they will never run cool until they have been thoroughly refitted.

To do this, rough out the brasses with a coarse file, and then with a smooth file; coat the journal surface with a thin coating of red lead or other coloring matter and oil, apply the brasses to the coated surface and rub them lightly back and forth; the high places will be indicated by the coloring matter adhering to them; scrape or file these high spots down and repeat the process till the color will adhere to the whole intended area of the bearing.

Another good way to bring a pair of brasses to wearing fit is to connect them in place, start the engine to running slowly and feed in a mixture of ground glass or other abrasive material and oil. This will not only bring the brasses to a perfect wearing surface but polish the crank pin as well. But before starting the engine to full speed the brasses should be taken apart and all of the grinding material carefully cleaned out.

Many preparations have been recommended for bringing hot bearings to a lower temperature; soapstone or talc, graphite, sulphur, white lead, red lead, rosin, bar soap, sapolio, and other abrasive soaps; tallow, suet, and many kinds of greases, either used singly or compounded together. But it has been the experience of the author that when a bearing can't be kept cool with an ordinary good oil it is time that it receive mechanical attention. It is like giving a man medicine when a surgical operation is needed.

BALL AND ROLLER BEARINGS.

The importance of reducing friction losses and increasing the efficiency in machinery has lead to the design and invention of many ingenious devices under the general name of anti-friction bearings.

Those that have been developed to a practical point and have been adopted by manufacturers of vehicles and machinery, have through the laws of "survival of the fittest" been narrowed down to two general classes, namely: ball bearings and roller bearings.

Balls and rollers both reduce friction by substituting rolling friction for sliding friction, ball bearings have points of contact, roller bearings have lines of contact, plain bearings have surfaces of contact.

BALL BEARINGS.

Ball bearings are those on which the load is sustained by and travels on a number of hardened steel balls; there are innumerable designs of ball bearings, and their application to machinery, but up to present writing their field of successful usefulness has been confined chiefly to bicycles and other vehicles and light running machinery, but they have not been used successfully on heavy machinery. Theoretically, hardened steel balls will sustain great pressures when running at high speed, yet in every day actual practice under severe duty, ball bearings have usually proven a failure.

Some makers of ball bearings show cuts of cars and other heavy machinery equipped with their make of bearings, and publish reports of tests to prove their efficiency, but the author has not been able to secure any authentic information from these makers; which leads him to believe that ball bearings for heavy continuous duty are yet in the experimental stage.

Of the economy of ball bearings there can be no question, as many tests have been made which have shown a reduction of friction of from 30 to 75, and even 90 per cent. over ordinary bearings.

As showing the difference in efficiency between plain and ball bearings, mention may be made of a series of tests made by Mr. Henry Souther, B.S., the results of which are shown in Table 13, page 196, a cylinder 2 feet 5 inches long and 2 feet 6 inches in diameter, weighing 5,000 pounds, was fitted with plain bearings and also with the Chapman Double Ball Bearing Co.'s type of ball bearings, and operated by an electric motor, the power being measured electrically.

TABLE XIII.

REPORT OF TEST OF CHAPMAN DOUBLE-BALL BEARING, MADE BY MR. HENRY SOUTHER.

	Chapman Double-Ball Bearing.	Plain Bearing.
Lubricant	Thin oil.	Thin oil.
Load in pounds	5,000	5,000
Revo. per minute	532	194
No. of Watts	205	766 to 1,093
H. P. from Watts	.274	1.027 to 1.465
Coef. from Watts	.00197	0.038 to .054
Spin	1 h., 14 m., 30 sec.	1 m., 5 sec.
Power to start	52 Am., 110 Volt.	30 Am., 110 Volt.
Starting load, 30″ pulley.	1 lb. (about.)	79.8 lbs.
Coef. of starting Fr..	.093	.138

Other tests have shown that with ball bearings increase of pressure did not result in a corresponding increase of friction, as is the case with plain bearings, neither does increase of velocity add appreciably to the resistance.

ROLLER BEARINGS.

The greatest reduction in friction loss in heavy machinery has been attained by the use of roller bearings, and by their use heavy shafting has been run at higher speeds and under greater pressures than would otherwise have been practicable.

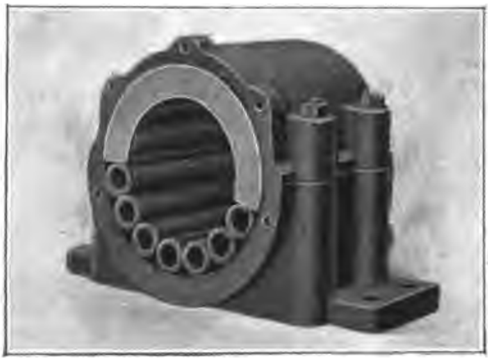

Fig. 52. Hyatt's Spiral Roller Bearing.

There are two general types of roller bearings, which do not differ much in their application; but in their construction, some makers use hardened steel rollers, while others use flexible spiral steel rollers.

Roller bearings are used by fitting the shaft with a steel sleeve, on which the rollers travel, the rollers are held in place by means of yokes or cages which are surrounded by the outer shell of the bearing.

Among the advantages of roller bearings over the plain bearing are reduction of friction loss, a saving of from 25 to 35 per cent. of the friction of line shafting, and as high as 50 and even 60 per cent. where the rollers are applied direct to the machine.

Other advantages will be found in decreased oil consumption, freedom from hot bearings and reduction of cost and maintenance of belting.

As illustrating the difference between a roller and a plain babbitted bearing the author quotes the Mossberg and Granville Mfg. Co.'s catalogue in which a report of a test is given where an end thrust roller bearing was weighed with 8,000 pounds, which with a radius of 10½ inches could be revolved with a pull of 20 pounds, while the same weight on a plain bearing required a pull of 400 pounds. See the following table:

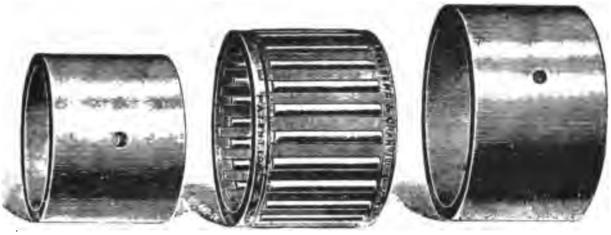

Fig. 53. Mossberg and Granville Co.'s Roller Bearing.

TABLE XIV.

Style of Bearing.	Area in Sq. in.	Total Load in Pounds.	Load in Pounds per Sq. in.	Starting Pull in Pounds. 10½" Lever.	Friction Co.Efficient
Plain ..	76.58	8,000	104.5	400	.05
Roller .	76.58	8,000	104.5	20	.0025

Another instance in which the cost of power and the saving effected has been reduced to dollars and cents is given in the case of an 84-inch rubber mixing machine which required 70 horse power to operate it under full load with plain bearings, while with roller bearings only 30 horse power are required. As one horse power cost about $35 a year there was effected in the operation of this machine a saving of about $1,400 a year.

Another case of a super-calendering machine in a paper mill that required about 40 horse power to operate with plain bearings, after being equipped with roller bearings only 20 horse power was required, making a saving of $800 to $1,200 a year in horse power cost.

OIL HOUSE METHODS, RECORDS, TOOLS, &c.

In a manufacturing or other establishment where oil is used in large quantities the utmost care should be exercised in the handling of it between the barrel and the machinery on which it is used. Proper means should be provided for the receiving and storage of the barrels and the issuing of the oils to the different departments. First in importance in this connection is the oil house, its location, convenience, etc.

In arranging for a situation for an oil house due regard must be given to convenience both for receiving the oils and greases and for their distribution.

In a large works where the oil is received in car load lots the oil house should be placed near a side track on the premises, and convenient to the works. The receiving platform should be on a level with the car floor, and large enough to hold a car load, or 60 barrels. If the oil is delivered by wagon it should be situated at the most convenient place on the premises that can be reached by a team.

In arranging the interior of an oil house one must be governed to a great extent by existing conditions. In building a new oil house it is an easy matter to arrange for the economical handling of the oil, but as is often the case, it is necessary to improvise an oil house in an old building or in the corner of the storeroom. In such case one must exercise considerable ingenuity to arrange for conveniently receiving and distributing the oil.

Figure 54 shows an interior view of an oil house which the author designed for a large steel works. The building is of brick, with a cement floor, and the roof of corrugated iron laid on an iron roof frame, thus making it practically fireproof. It was placed in the mill yard adjoining a side-track and was also convenient for teams. In the end of the oil house and above the tanks is a door through which the barrels are rolled onto a pair of angle-iron skids which are placed about a foot or so above the tanks and extended from one end of the oil house to the other.

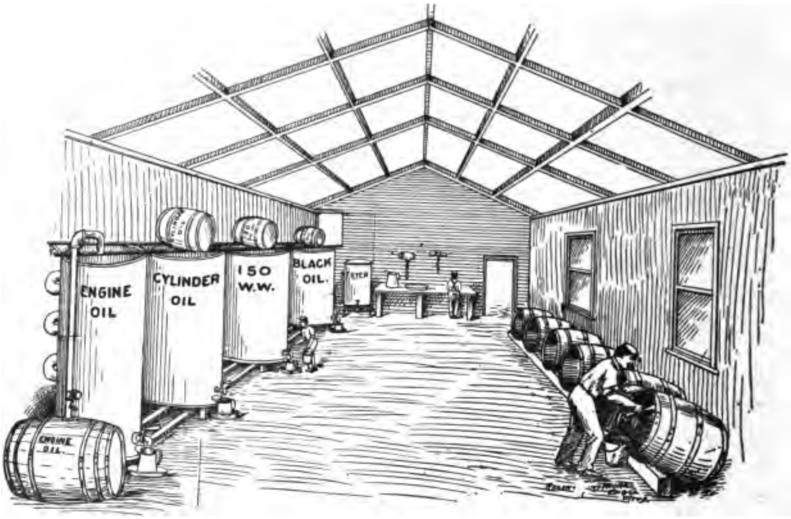

Fig. 54. Oil House.

The barrels are rolled in on the skids and the bungs chipped out with a chisel or drawn out with a special tool and a taper wooden plug about six or eight inches long inserted in the bung-hole. The barrel is then rolled till the bung-hole is over the proper tank, and the plug is withdrawn, allowing the oil to run into the tank. The tanks are made of heavy galvanized sheet steel holding ten barrels, or 500 gallons each. The tanks stand in a row along one side of the oil house and rest on two angle-iron pieces similar to the barrel skids and about 18 inches above the floor. In the tops of the tanks are set removable trays provided with fine perforated metal screens so as to prevent chips, dirt or lint from getting into the tanks.

Where it is not convenient to empty the barrels from above the tanks they can be rolled in on the oil-house floor and the oil pumped out with a small hand rotary pump.

The oil is drawn off through "key faucets" so that no one can draw oil without the proper key to open the faucets. Under the faucets are suitable sheet steel pans to catch the drips. Against the wall back of the tanks is a large steam coil so that the room can be kept warm enough to make the heavier oils flow freely in cold weather.

In the winter the barrels should be kept in the oil house on the skids for several days before emptying them, in order that the oil may become thoroughly warm and drain away clean from the inside of the barrel.

On the side of the oil house opposite the tanks are kept the grease barrels. These stand on end and as the roll greases are very dense and heavy and require to be taken out with a spade or shovel, it is necessary that the head of the barrel be taken out. This should be done carefully, and when the barrels are empty the heads should be replaced and the hoops tightened up again. The barrels thus treated will bring a better price than if the heads were destroyed. The men who use the grease are provided with strong sheet iron steel buckets holding 25 pounds each, and the grease is shoveled out of the barrels with a spade, that will scrape the grease clean away from the inside of the barrel.

The oil house adjoins the store house and the storekeeper or his assistant gives out and charges to its proper department all oils and greases. Every engineer, oiler or other person whose duty it is to look after the lubrication of the engines, pumps or other machinery is provided with sheet steel cans holding one, two or three gallons each, according to the amount of oil needed. The oil house is only open for the delivery of oil and grease from 8 to 10 o'clock in the forenoon and from 4 to 6 in the afternoon.

Each engine and department is allowed a certain amount of oil per day. The proper amount is determined by the Chief Engineer or Master Mechanic, and if for any reason it is necessary to have more than the regular allowance an order from the Chief Engineer or Master Mechanic must be presented to the storekeeper.

Outside the oil house a place is provided for the storage of empty barrels, these should be placed on their sides with the bung-holes down, so as to prevent dirt from getting in. When a sufficient number of barrels have accumulated to make a carload (about 140 barrels), they should be shipped back to the oil dealer who will credit the works with the amount, according to the grade of the barrels.

Barrels which have contained burning oils, gasolines, benzine and turpentine, are graded as first class barrels; engine and cylinder oil, machinery, lard, neatsfoot and miners' oil barrels are graded as second class; black oil, car oil, crank-case oil and other dark heavy oil barrels are known as third class, and grease, tar, paint and varnish, and linseed oil barrels are called fourth class barrels.

A daily record is kept of all oil and grease issued during the day on blanks provided for this purpose and each gallon of oil and pound of grease is charged to its proper department. Table XVI. shows an oil house blank suitable for a large steel works, and on it will be shown at a glance the amount of oil and grease drawn by each department. On this daily report is also entered the number of barrels, gallons and pounds of lubricants received, and the initials and number of the car if received by rail. If empty barrels are returned the number and grade and the initials and number of the car they were loaded into are also marked on the blank.

At the end of the month the daily reports are condensed into a monthly statement showing the total amount of lubricants used. These items multiplied by the price per pound or gallon will give the cost of lubrication for each department for the month, and the total amounts and cost for the whole works. On the monthly report is also entered the number of barrels and cost of lubricants received and the credits for empty barrels returned.

In some works it is customary to reduce the cost of the lubrication to a tonnage basis; that is, by dividing the net cost of the lubricants by the output of the works in tons, will give the cost per ton for lubrication.

TABLE XVI.

DAILY OIL HOUSE REPORT.

Department.	No. 1 Cyl'der Oil.	No. 2 Cyl'der Oil.	Engine Oil.	Black Oil.	Lard Oil.	Torch Oil.	Signal Oil.	Tallow Comp'd.	Hot Neck Grease.	Gear Coating.	Cup Grease.
Blooming Mill	3	2	6	7	.....	2	.....	50	.....	50	.....
Blast Furnace	2	1	3	5	.....	4	2	.....	.....	.....	10
Sheet Mill	4	3	4	6	.....	2	.....	50	150	75	5
Electrical Department	2	.....	4	.....	.....	.....	.....	.....	.....	.....	5
27-inch Mill	3	2	3	7	.....	.....	.....	100	.....	100	....
Locomotives	1	.....	2	.....	.....	.....	1	.....	.....	.....	.....
Bar and Muck Mill	2	3	3	6	.....	4	.....	50	.....	.....	10
Yard Machinery	.....	.....	.....	3	.....	2	.....	.....	.....	.....	.....
Machine Shop	1	.....	1	.....	2	.....	.....	.....	.....	.....	.....
Stokers and Pumps	.....	2	1	3	.....	4	.....	.....	.....	.....	.....
Open Hearth Department	.....	2	3	4	.....	2	.....	.....	.....	.....	.....
Sundries	.....	1	.....	2	.....	5	.....	.....	.....	.....	.....
Total	18	16	30	43	2	25	3	250	150	225	30

Remarks: Oil and Grease received this dav.

2 bbls.—	102	gals.	No. 1 Cyl. Oil
1 "	52	"	" 2 " "
4 "	207	"	Black "
1 "	51½	"	Lard "
9	412½		

Empty bbls. returned:

1st class......	...
2d "	22
3d "	...
4th "	...

TABLE XVII.

MONTHLY OIL HOUSE REPORT.

DEPARTMENT.	No. 1 Cyl'der Oil.	No. 2 Cyl'der Oil.	Engine Oil.	Black Oil.	Lard Oil.	Torch Oil.	Signal Oil.	Tallow Comp'd.	Hot Neck Grease.	Gear Coating.	Cup Grease.
Blooming Mill	72	41	107	122	.....	41	.....	925	600	725	.....
Blast Furnace	91	37	97	123	.....	120	5	.....	.....	.....	25
Sheet Mill	86	21	69	141	.....	51	.....	725	1200	125	10
Electric Department	63	.....	104	.....	.....	.....	.....	.....	.....	.....	20
27-inch Mill	58	18	88	209	.....	.....	.....	1000	450	275	.....
Locomotives	8	.....	16	.....	.....	.....	4	.....	.....	.....	.....
Bar and Muck Mill	49	51	90	188	.....	77	.....	475	.....	100	10
Yard Machinery	.....	.....	.....	75	.....	41					
Machine Shop	5	.....	6	.....	10	.....					
Stokers and Pumps	.....	14	7	12	.....	48					
Open Hearth Department	.....	12	39	62	.....	28					
Sundries	.....	4	.....	17	.....	108					
Total Amount	432	198	623	649	10	514	9	3125	2250	1225	65
Total cost	$184.40	$55.44	$99.68	$90.15½	$4.50	$30.84	$3.60	$93.75	$45.00	$24.50	$3.25

Total cost	$635.11½
Credit emty barrels	87.95
Net cost	$547.16½
Number of tons	12682
Cost per ton	.04.47.2

EMPTY BARRELS RETURNED,
P. R. R. car No. 12121:

40 1st class	$32.00
55 2d class	33.00
51 3d class	22 95
145	$87.95

Oil and Grease received this month:

8 bbls.	408 gallons	No. 1 Cylinder Oil
12 "	611 "	Engine "
12 "	609 "	Black "

Reports of this kind while requiring some clerical work will enable the manager of a works, by comparing with previous reports, to determine if the lubricants are being used economically, and by reducing the cost to a tonnage basis it will be seen at a glance if the cost per ton is increasing or decreasing.

In a plant where the oil consumption only amounts to a few barrels a month, an oil room may be easily improvised. Where it is possible to do so tanks should be dispensed with and the oil drawn directly from the barrels, thus saving the time and annoyance of pumping or pouring the oil from the barrels into the tanks, then if the oil be dirty or not up to the standard in quality it is easy to place the blame, while if this be not noticed till the oil is put in the tanks it would be a question whether the oil had been of poor quality when received or had become contaminated in the tank.

Another thing, if a fire should occur in the building the oil barrels can be easily rolled out to a place of safety, while tanks would be almost immovable and the first touch of flame would melt the solder and allow the oil to flow out, and by igniting, greatly increase the danger.

Where the plant is not very large and only one or two persons draw the oil supply a record blank as shown in table XV., page 208, would be sufficient, the engineers or oilers can mark down in their proper places the number of quarts or gallons taken. It will also be noticed that there is a place to record oil returned to the filter.

Subtracting the amount of filtered oil from the total amount of engine oil issued will give the net consumption of engine oil.

TABLE XV.

January	Cylinder Oil.	Engine Oil	Black Oil.	Grease.	Returned filters.
1	2	6	8	.....	3
2	1½	7	7	12	4
3	2	5	9	8	5
4	1	7	8	5	5
5	1	6	8	2	4
6	1	7	9	8	5
7	2	6	8	5	4
8	2	8	7	3	5
9	2	9	7	.....	6
10	1½	9	.....	8	6
11	1½	7	.....	.....	5
12	1	7	8	10	5
13	1	8	.....	.....	3
14	1½	7	3	.....	4
15	1	7	.....	5	6
16	2	8	.....	.....	6
17	1	5	.....	.....	4
18	1	9	8	5	6
19	2	9	.....	.....	7
20	2	8	7	.....	6
21	1½	5	.....	.....	4
22	1½	7	.....	.....	6
23	2	7	.....	10	6
24	1	6	5	.....	5
25	1	6	.....	.....	5
26	1½	8	.....	.....	5
27	2	8	.....	.....	7
28	2	7	8	.....	6
29	1	6	.....	.....	6
30	2	7	.....	.....	6
31	1½	7	.....	.....	6
Total	47	219	110	81	161

47 gals. cylinder oil at .50	$18.80
219 gals. engine oil issued.	
161 gals. engine oil returned to filter.	
58 gals. engine oil at .20	11.60
110 gals. black oil at .08	8.80
81 pounds grease at .05	4.05
Total cost for month	$43.25

....*Engineer.*

GAUGING BARRELS.

Every oil house or storeroom should be provided with suitable tools and appliances for measuring the oil, and among the most important is a reliable gauge rod and wantage stick, the first to measure the contents of the barrel and the second to measure the amount of shortage or leakage that there may be.

Fig. 55 shows cuts of these instruments manufactured by the United States Gauging Rod Co. The gauge rod is made of some hard wood such as hickory, maple or box wood, is three feet long and wedge-shaped at one end; the wedge is tipped with brass to prevent wear, the two sides not tapered are marked off in inches and parts of inches; on one of the other sides is marked the scale which shows the capacity of the packages.

The wantage stick is also made of hard wood, three-quarters of an inch square and 17 inches long, with a brass lip or projection extending out about half an inch and about 4 inches from the upper end. The stick is marked with eight scales, to show the number of gallons out of different size packages.

DIRECTIONS.

To gauge the contents of a barrel place it on its side with the

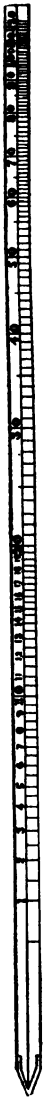

Fig. 55.
Gauging
Rod.

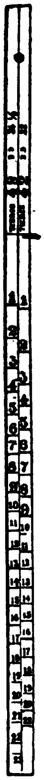

Fig. 56.
Wantage
Stick.

bung-hole up, insert the gauge-rod in a diagonal direction through the bung-hole till the taper end touches the chime or the place where the head fits into the staves, as will be seen in Fig. 57, at the same time keeping the side of the rod on which the number of gallons is marked uppermost.

Then notice the point on the rod where a line drawn across the inside of the bung-hole will come, and note the figure on the rod at that point, being careful not to confound the inch scale with the gallon scale. The point noted will indicate the number of gallons that the barrel will contain.

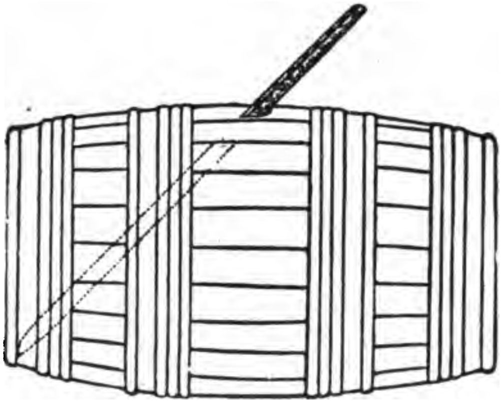

Fig. 57. Gauging a Barrel.

If the bung-hole was exactly in the center or an equal distance between the two ends, one insertion of the rod would be sufficient to give its capacity, but it is always well to measure towards both ends of the barrel. If there is a difference the average of the two should be taken.

If the barrel on account of leakage or other cause should not be filled to the proper height the amount of loss can be determined by the use of the wantage stick.

It should be remembered that oil barrels are never filled completely; owing to the expansion and contraction of oil due to changes of temperature, it is customary to fill barrels so that at 60 degrees Fahr. there will be one gallon less than its actual capacity. A barrel guaging 50 gallons will contain 49 gallons, and be so marked on the head.

If the barrels were entirely filled at a low temperature and stood in a warm room any length of time the expansion of the oil would force the bung out, or cause it to leak at the staves.

Before using the wantage stick first note that it has eight scales. The 10-gallon scale will show the shortage in packages containing up to 15 gallons, the 16 scale will show the shortage in packages containing from 15 to 20 gallons, the 24 scale will show the shortage in packages containing from 20 to 30 gallons, the 32 scale should be used in measuring packages containing from 30 to 40 gallons, the 42 scale in barrels containing from 40 to 45 gallons, the 46 scale in barrels containing from 45 to 48 gallons, the 48 scale in barrels containing from 48 to 51 gallons, and the 52 scale in barrels containing from 51 to 56 gallons.

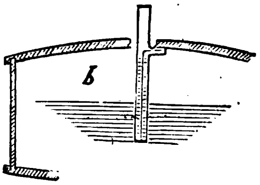

Fig. 58. To Measure the Outage.

But as ordinary oil barrels contain from 48 to 54 gallons the only scales which will be needed will be the 46, the 48 and the 52, and to avoid confusion and chances of error all the other scales can be obliterated.

To use the wantage stick place the barrel as in guaging, insert the stick carefully till the brass lip or projection will just come on the under side of the stave, as shown in Fig. 56, being careful to not let the stick go any deeper; withdraw the stick and note the wetted line, read down from the lip on the scale corresponding to the capacity of the barrel, the figure nearest the wet line will give the number of gallons that the barrel is short of being full.

In case that the barrel is over half empty the wantage stick will not reach to the surface of the oil. In that case insert the gauge-rod, point down, straight through the bung-hole to the bottom, draw it out and note how far it is wet; place the rod alongside the wantage stick on the side of the stick that corresponds with the size of the barrel. For instance, with a 48-gallon barrel place it against the 48 line or scale.

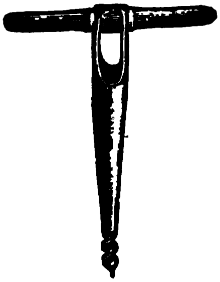

Fig. 59. Auger and Reamer.

Place the point of the rod that was at the bottom of the barrel on a line with the brass lip on the stick. The mark on the stick that comes opposite the wet line on the rod will indicate the number of gallons remaining in the barrel.

A little practice will enable one to use these tools with accuracy and ease.

Among other tools that will be found to be useful in the oil house is a combination bunghole auger and reamer (See Fig. 59), which can also be used to bore spigot holes.

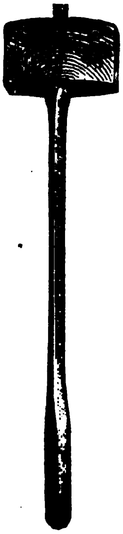

Fig. 60. Bung Starter.

Fig. 60 shows a bung starter for loosening the bung by striking the stave near the bung.

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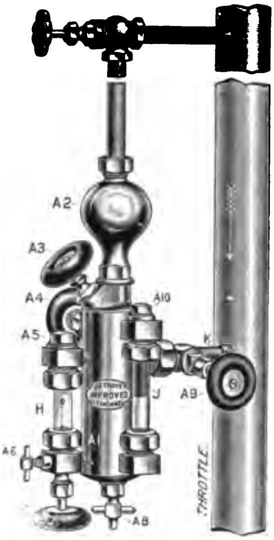

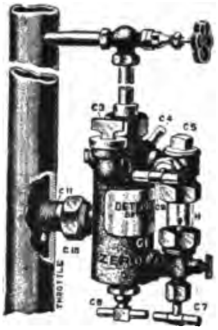

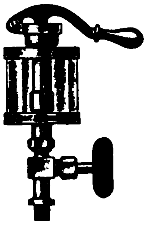

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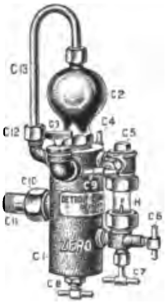

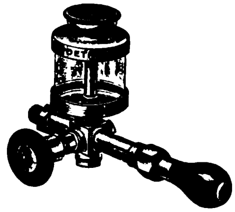

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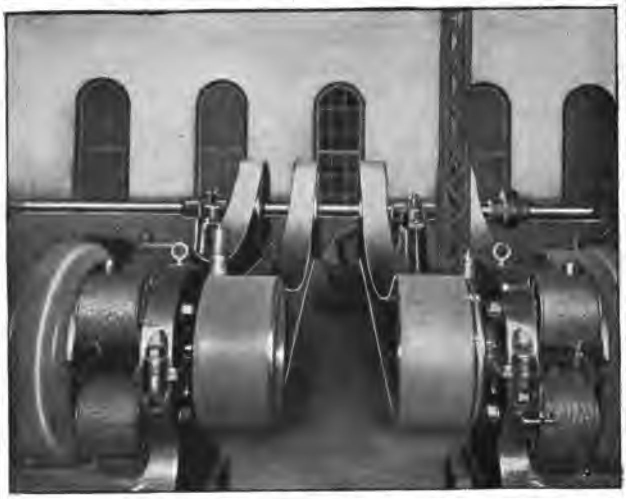

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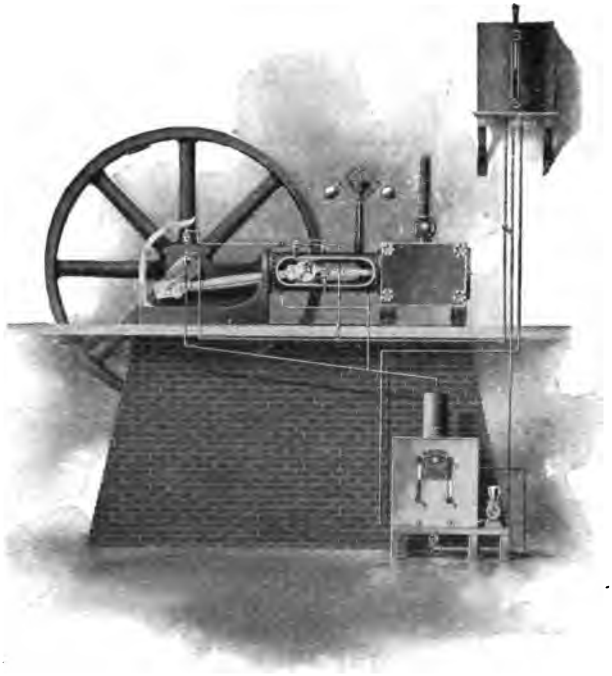

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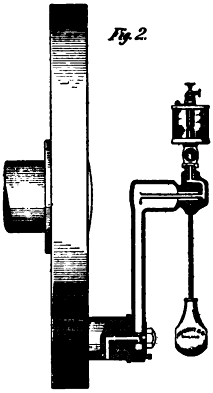

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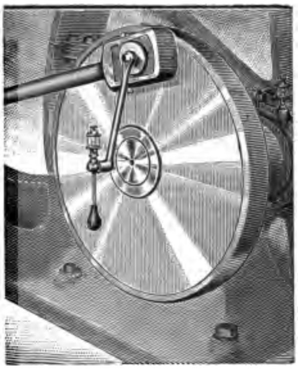

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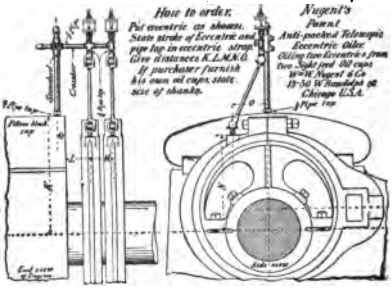

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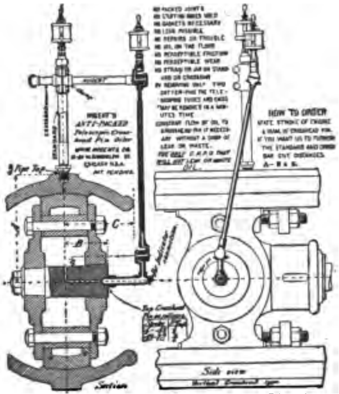
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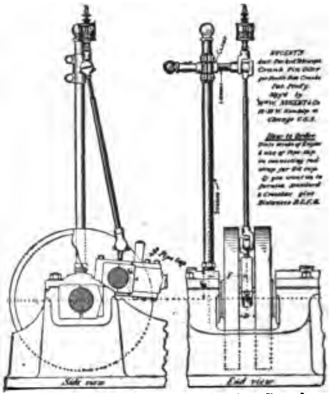

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